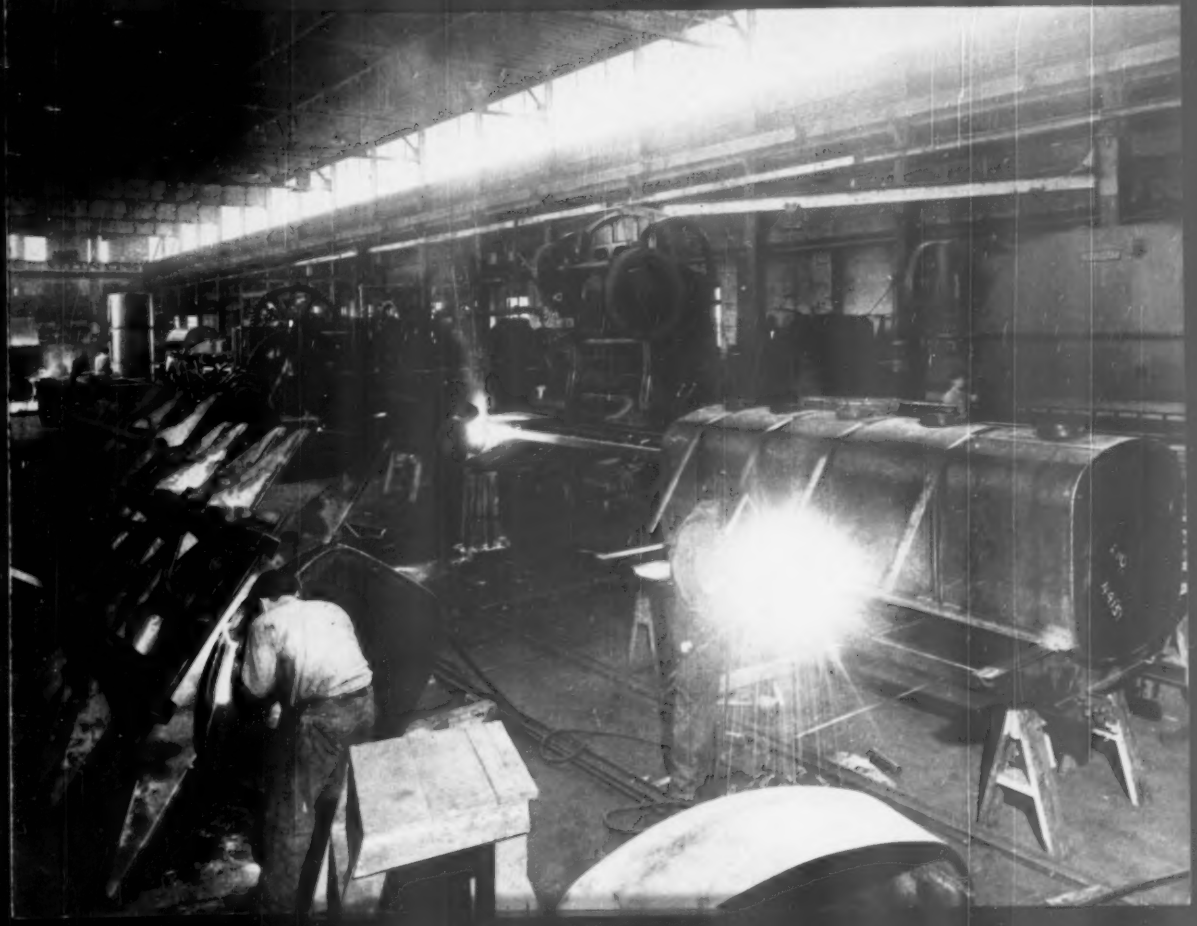
WELDING JOURNAL



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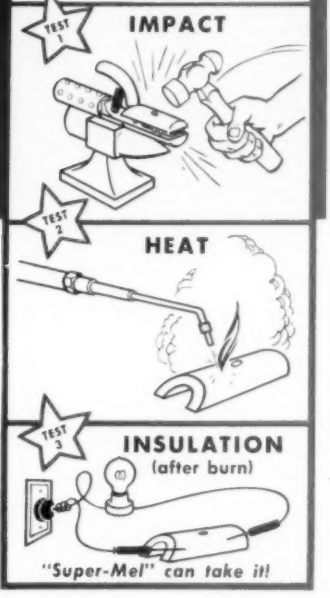

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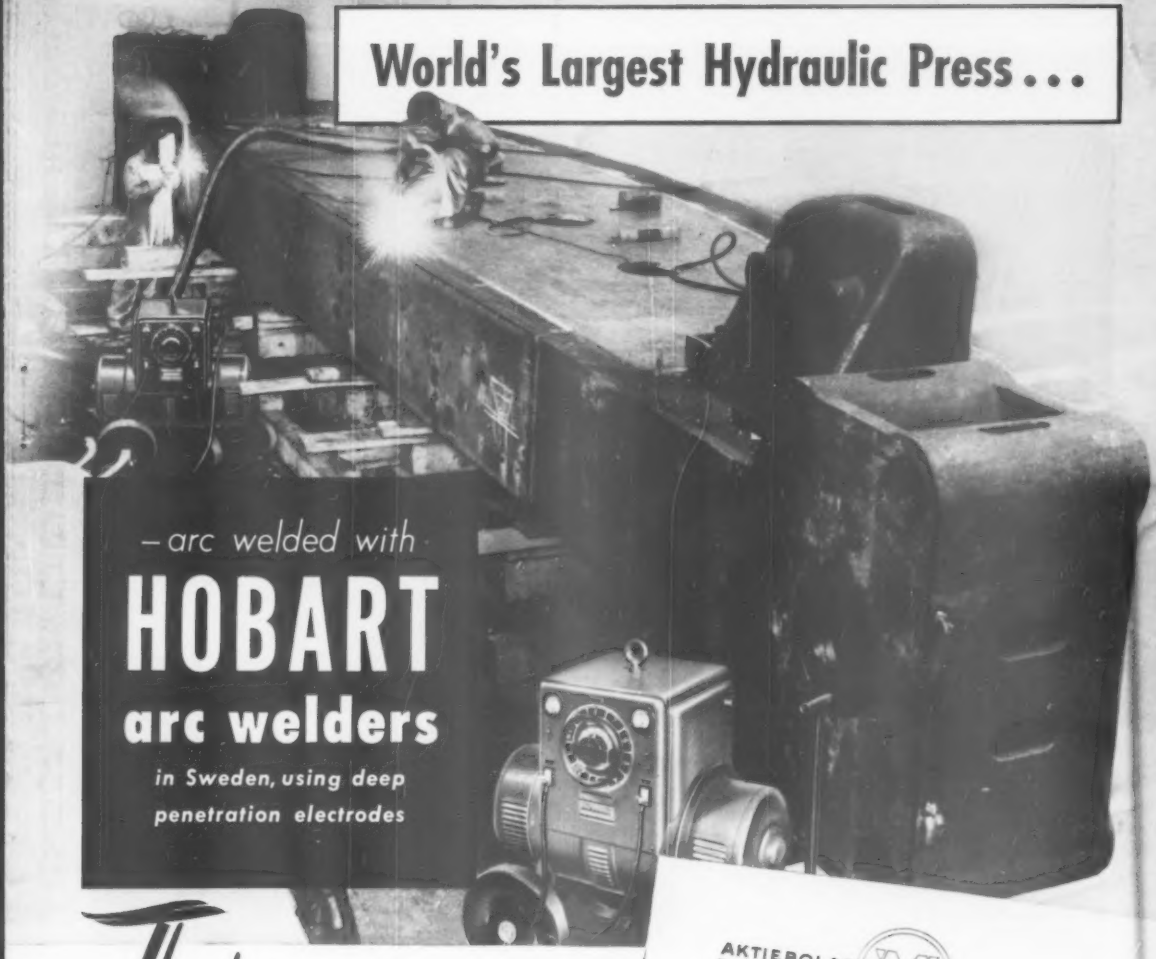

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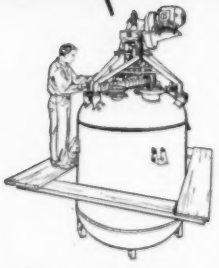

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cover: Manufacturing Truck Tanks. *Courtesy Brown Steel Tank Company, Minneapolis, Minn.*

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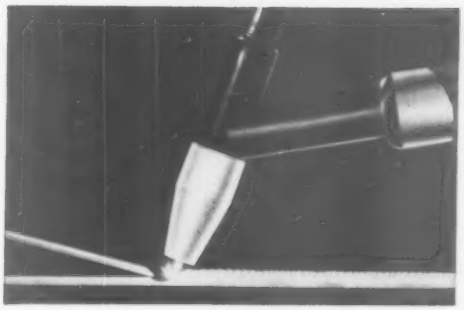
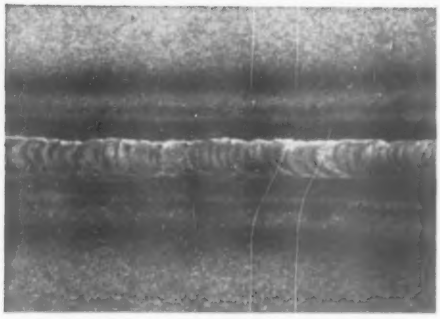
Weld Sheet Steel with the HELIARC torch

Trade-Mark



and wipe out one complete operation



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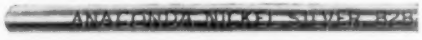

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The WELDING JOURNAL

volume 29 May 1950 number 5

Designing for Welding

In 1948, the American Welding Society inaugurated a series of Educational Lectures as a new activity during the Annual Meeting. The 1949 series repoduced herewith considers the application of welding to the work of industry

by Harry W. Pierce

BEFORE an arc can be struck on metal the product must be designed to serve its purpose, the materials chosen and the method of fabrication determined in more or less detail. By the drawing details and specifications of his work the designer, intentionally or not, quite frequently chooses the method the shop must follow in executing the work. With this we have little to quarrel; it is, in fact, the lack of complete detail on the part of the designer which frequently handicaps a welded design.

Since the decision to use welding is usually made at the drafting board—and since its successful application depends largely on the designer—this current series is addressed principally to the designer in the metal fabricating industry. This does not in any way diminish the responsibility and participation of the shop man. In a field so dynamic and changing so swiftly, more than the usual cooperation and liaison is required. The designer must know the limitations and specific requirements of the processes as well as the equipment of his shop. He should have a good working knowledge of the shop problems of shrinkage and distortion. He must have accurate knowledge not only of suitability but availability of materials or the costs of "extras."

The metal fabricating industry, considered broadly, consists of those who convert basic metal forms, such as ingots, pigs, plates, shapes, bars and tubes into machines, buildings, bridges, ships and all manner of metal products. The finished part may be an integral item, formed by casting, forging or machining, from a single homogeneous piece of metal, or it may be a complicated arrangement of many pieces, sometimes of quite different metallurgy, wherein the fixed parts are bolted, riveted, welded, brazed, soldered or clamped shrunk together. The combinations of processes are almost infinite—it is the designer's task to select those which best satisfy his problem, with due regard to all factors involved.

We are here considering a method, or rather a family of methods of joining metals, namely, the welding processes. When we think of bridges, ships and many structures employing plates or shapes, we think of welding as an alternate to riveting or bolting. But by the nature of the weld, by reason of joining the two or more parts into a single, if not a homogeneous whole, it is also an alternate to many other processes, such as casting, forging and forming. It is well within the realm of the possible to say that it could supplant any or all, but such a course is a disservice. Welding—or any process—can be applied in a way which is not sound from either an engineering or an economic standpoint. Welding justifies its use only where it provides an equal or better product at less cost, or where other factors, such as time, weight or availability, are paramount.

Field for Welding

Competitive in some applications, it is frequently a supplementary method. The field is so wide, however, and so fertile for pioneering, that almost every product deserves close scrutiny for possible economies by its use. Certainly no field offers the ingenious, inventive and wide-awake designer greater possibilities. It is puzzling that more engineering designers are not at least intrigued by welding, if for no other reason than it permits almost unlimited exercise of their own ingenuity with remarkably few artificial barriers.

It is this freedom from many of the handicaps of other processes that should appeal to the man with initiative. To a great many, for example, the simplicity and low cost of the equipment ordinarily required,

Harry W. Pierce is Assistant to the President, New York Shipbuilding Corp., Camden, N. J.

directly and indirectly, makes possible items of production hereto impossible for many a plant to consider, either through lack of facilities or an impossible capital investment in heavy industrial machines. Many of welding's economies spring from the fact that the raw materials are largely the cheapest and most easily obtainable basic forms—plates, sheets, shapes, bars and tubes. Further, many of the welding processes permit extremely simple jointing of shapes or tubes, symmetrical about one or more axes—basically efficient as well as attractive. The comparative ease with which many different metals can be jointed or surfaced by welding permits wide freedom in placing the right material at the right place. The advantage of rolled steel in strength and stiffness over cast iron presents obvious opportunity for savings where these characteristics are major considerations. Material savings are real from the elimination of laps, straps, clips or connecting angles in structures, full plate strength can be had in joints plus water or gas tightness in a single operation in all manner of containers from ships to pressure vessels.

To realize these savings, and to obtain better products at less cost requires, however, design work tailored to the welding processes. Duplication of the form of a previous method may be quite possible, but may be like the classic Chinese duplication of an old pair of pants, identical to the last patch. Every process has limitations—welding included, although it may have a few less than most—and the carbon copy approach is more likely than not to retain undesirable features inherent in the process formerly used. Hence the necessity of examining the new product or the redesign of an old one from the same viewpoint: the basic purpose or function of the item. If a welding application is indicated, then design with welding in mind.

The Welding Processes

Therefore, let us begin by reviewing and taking stock of the tools we have—in other words, the welding processes which are well-proved and in general use, although they may not be immediately available in any one shop or plant. First, let us consider these tools by referring to Fig. 1. The figure as shown includes only the major divisions of the Master Chart. For the complete breakdown, including all of the characteristics of the welding processes, the reader is referred to the Standard Master Chart of Welding Processes, published by the American Welding Society. This simplified version, however, points out the range of processes which a designer should have some familiarity with in order to make an intelligent choice of the method of fabricating any particular item. There is overlap and duplication to a degree not commonly realized. For example, most of us know that either a gas torch or a metallic electrode can be used to make a butt joint between two pieces of half-inch metal; perhaps fewer of us are aware that resistance welding of equal or heavier thicknesses is now quite possible, even if not commonplace. Some of the old fields of resistance welding, such as the spot welding or seam welding of light sheet metal parts, are being invaded by specialized forms of arc and gas welding.

Starting with arc welding, since it probably represents the heavy part of welding applications, we find that it is an extraordinarily versatile method and invades almost every field of metal fabrication. It is at its best, however, in plate and shape fabrication, in the field of pressure vessels, structures, ships, machine tools, piping and particularly in steel and its alloys, where the thickness is from $^1/_8$ in. or a little more upward to plate limits. A wide range of metallic electrodes, tailored to various base metals, are well known. But there are subclassifications which are primarily used in other fields, carbon electrodes in the nonferrous field, atomic-hydrogen in sheet metal fabrication, ferrous and nonferrous, and the relatively new inert-gas

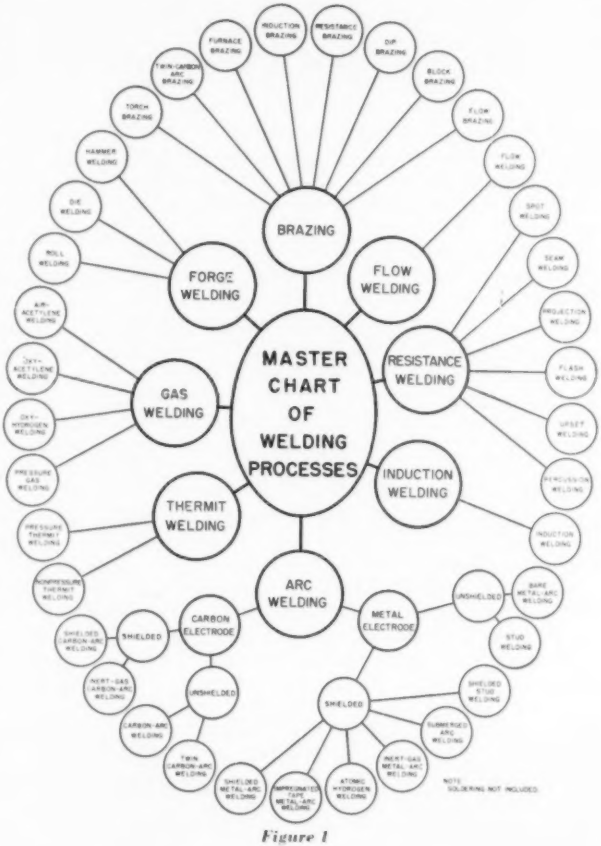

Figure 1

metal arc which is expanding rapidly from aluminum and magnesium to other applications, notably in the chrome-nickel alloys in thin material.

Gas welding has been superseded by the metallic arc in most steel plate and shape fabrication, but still has a firm hold in many fields, ranging from light sheet steel to nonferrous, cast iron and so forth. Small diameter and thin wall pipe is an excellent application and pressure gas welding on heavier pipe in production quantities is a newer field.

It is well here to refer to gas cutting, since this wide field of application for gases is the perfect complement to many of the welding methods. The ease with which material may be prepared for welded assembly without the necessity of heavy shearing and planing tools makes it an inseparable adjunct to plate and shape fabrication.

Thermit welding not only occupies a place in large-scale repairs, it is at its best in the joining of very heavy sections such as rails and, particularly where the cross section to be welded approaches a square or round area of considerable size.

Resistance welding is still most closely identified with sheet metal fabrication—from vent ducts to auto bodies, and the high production of an infinite variety of small parts. Advances in this field have been noteworthy, however, and it is fast invading the heavier fabrication fields. While some of its most noteworthy applications are with intricate and costly machines of special design for the mass production of a single part or joint, the versatility of standard machines with a limited range of electrode forms and dies is amazing—provided that the designer works his joint designs around the possibilities, and limitations, of the equipment.

Because of their more limited fields, and hence of less interest to a group, we are arbitrarily skipping forge, flow and induction welding. Nor does time and space permit more than a passing reference to brazing. In many, many applications, however, the brazed joint, particularly in tubing, or in the complete and gas-tight attachment of small parts, is an ideal, low-cost high-production method—one not to be overlooked in a preliminary study of a product and perhaps an ideal alternative if fusion temperatures are undesirable.

We see, therefore, that choice of the fabrication method is a great deal broader than "welding vs. castings" or "welding vs. riveting" and so on. It may well be between spot welding, inert arc welding or riveting, or perhaps a choice between an arc weld, a casting or a thermit weld. And it can easily happen that all may have a place in a finished assembly, in order that all requirements be satisfied at minimum cost.

Design Considerations

With a fabrication problem before him, the designer necessarily begins his study by consideration of the following factors:

1. Form
2. Material
3. Weight limitations
4. Time
5. Facilities or sources available
6. The quantity to be produced
7. Appearance
8. Cost

In defense of placing cost last in this list, when most of us will agree it is paramount in most of our thinking, let me suggest that it is generally but not always the final and deciding factor. When other requirements are satisfied, in whole or in part, cost is determining.

Nor are these factors independent of each other. The cost of a particular design, if only one item is to be made, may be entirely out of line, yet be the lowest per unit if a thousand or ten thousand pieces are to be made. Likewise, the most economical method may require facilities which are not available, and which are not economically justified by the number involved. The best design may not be the one which can be produced most quickly, due either to availability of equipment or material, and time might be an all-important factor. The factors have been listed in approximately the sequence in which they are usually considered.

For example, a bridge or a crane suggests a fabrication of plate and shapes, or perhaps shapes only; a tank, plates or sheet fabrication, perhaps rolled cylinders or large pipe; a machine base, a plate weldment or a casting. Almost automatically, certain fabricating processes are eliminated. Next, the material consideration, in whole or in part; the metallurgy required for the service, special alloys and the thicknesses involved. Aside from waste and extra cost in material, weight may be a highly important factor and, as in the case of air-frame parts, perhaps controlling. Time—here the over-all or calendar time to produce, not the man-hours of labor alone which will receive more consideration under cost—is not ordinarily too important in ordinary production, but might be critical in a replacement or special item. A plant designer naturally thinks of the facilities either available in his plant, or among his subcontractors or usual sources of supply. However, the quantity to be produced may justify an expenditure for new equipment in order that the unit cost be lowered. Further the quantity may justify jigs and fixtures, patterns or miscellaneous items, required by one of the processes to be considered. Final appearance may or may not be a factor; but eye appeal is becoming more and more important, and certainly clean and functional design does no harm to any engineering product and may be worth extra cost.

Finally, of the methods which remain under consideration, which will result in minimum cost?

At this point let us review the case for welded design in the light of the foregoing line of reasoning.

1. With the multiplicity of standard shapes, bars, pipe and tube sizes readily available and as readily and economically cut to shape, plate to be formed by relatively simple equipment available in most shops, together with the facility with which parts may be joined

by welding, form is rarely in itself a serious bar to welding.

2. Welding has come to the point where weldability becomes a term of degree. Some materials are more easily welded than others—that is, they require fewer precautions, perhaps, and hence cost may be affected, but few materials rule out welding as a means of fabrication. By one process or another, the range of thicknesses which can be joined is likewise almost unlimited.

3. Where weight is a factor, the welding processes really come into their own. We have spoken of the weight savings of mild steel over cast iron, of the simple butt and T-joint vs. riveted straps or laps and connecting angles. Weight and material savings are of real consequence even if no special premium is placed on weight saving.

4. Over-all time is usually a problem of material and parts supply from many vendors. Certainly a process which can use basic materials, most of which are carried in the stocks of a fabricator and in any event are most quickly obtainable, has a long advantage.

5. The facilities for most welding jobs are comparatively simple and now available in most metal fabricating shops. Except for highly specialized equipment, installation or expansion is relatively low in cost.

6. When large production runs are contemplated automatic and semiautomatic welding processes, and other of its specialized forms, frequently result in extremely large savings in man-hours. On the other hand, in small quantities the wide adaptability of manual methods, supplemented by simple jigs and fixtures, creates a natural field for welding.

7. Appearance depends almost solely on the skill and ability of the designer—assuming, of course, a competent shop crew. Certainly, welding need not be the reason for any lack of eye-appeal.

8. Cost. This all important consideration brings us to the heart of this discussion. It is our theme, this year, to point the way to lower costs, as well as better products, by welding. This, in turn, requires a careful study of certain details of the welding processes, and the development of the factors making up good welded design.

We will not, however, use many comparative figures or long statistics on savings in the course of this paper. At best, exact cost comparisons hold good for only a particular job done in certain ways, at a particular shop. Percentage savings are perhaps only a little better. At worst, an array of figures obscures the real objective, and in this case we want to look at the forest, not the trees. Thousands of successful welding applications have proved that cost savings are there, our purpose is to bring out the factors—in the field of design—on which they depend.

Joints

Whether the welding process is being used to connect plates and shapes, in place of rivets or bolts, or to make up a replacement of a casting or forging, we are joining metals. Therefore in design for welding we are chiefly concerned with joints—when to use a joint, how to weld it, where to place it, what to do and what not to do. It appears both logical and fundamental to first consider the various forms of welded joints and methods applicable to each. Although there are other and important considerations in the economical design of weldments of any sort, we sooner or later come back to those important when, what, where and how questions of the joint.

Fortunately, the classification of fundamental joints is quite simple. Greater complication sets in when we discuss the methods applicable to these basic joints. Chaos would result in these lectures if we went into a discussion of bevels, root openings, root faces and all the detail, vital as it is in the production of satisfactory welding.

Exact edge preparation for these joints, particularly the groove joints, is hardly within the scope of lectures intended to be on fundamentals. Dependent on shop practice and to some extent on codes, rules or specifications, it is sufficient here to state that the preparation must be such that the joint can be made. Again there is necessity for liaison between shop and drawing room. We shall therefore assume that such liaison exists, or is established through standards of the plant or by code or rule. In any case, the preparation should be clearly and definitely shown on the drawing.

Figure 2 shows the standard classification of joints—some five classifications will cover almost every conceivable situation, with due regard to multiple intersections, intersections at some angle between 0 and 90°

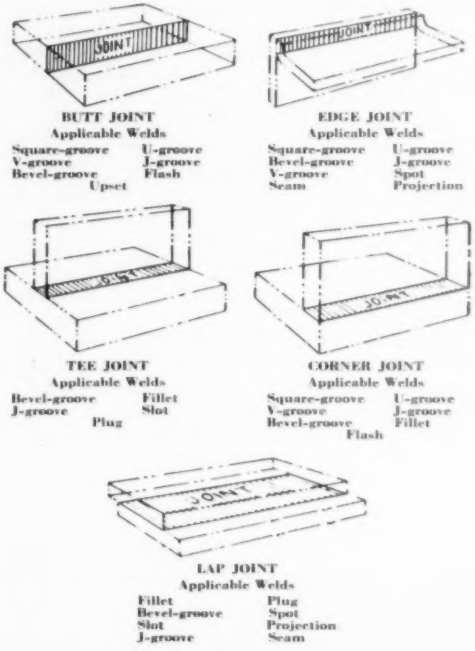

Fig. 2 Types of joint

and so forth, all of which, on analysis, can really be at least roughly classified under these five.

Under each joint appears a brief list of the welds which may be used, with due regard to the nature of the material and the thickness of the parts. This figure does not, of course, give any indication of the joint preparation before welding which may or may not be required. To proceed a step further, let us consider the welds in some greater detail, starting with the butt joint. This joint is one of the prize advantages of welding—for by its use we can join two plates in plane, and in a great many materials, and we can obtain, if we wish, any joint efficiency up to full plate strength. There are, of course, cases of heat-treated or cold-worked materials which are annealed by the heat, or those in which the as-cast form of the weld is lower in physical properties than the rolled or wrought parent metal. In these cases, the welded joint will have something less than 100% efficiency, unless it can be obtained by subsequent treatment. If the latter is either impossible or uneconomical, the designer is forced to accept a lower efficiency—a position which, it can be noted, is one in which he has been for a great many years.

The groove welds here shown in Fig. 3 begin to indicate the diversity of action open to the designer, and it is worth pointing out why there should be such a variety in use. Of course the groove and bevels are simply for the purpose of obtaining complete fusion if complete fusion is a requirement. The exact shapes, bevel angles and so forth, when not covered by specification, are matters to be thrashed out and proved by the individual plant. It is largely a matter of the particular procedure used. This is not to infer that the detail, unless covered by standard drawings or practice, should not appear on the drawing. The designed strength of

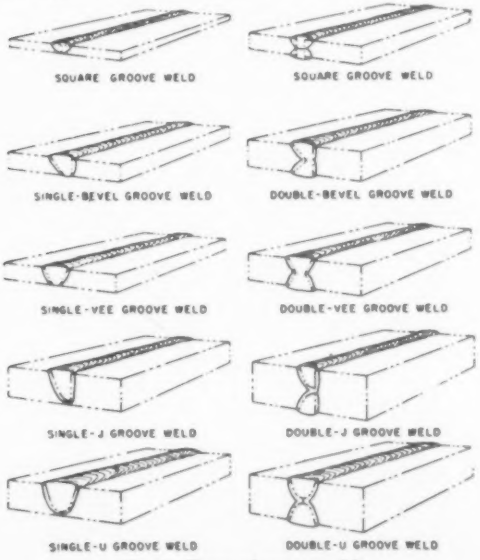

Fig. 3 Types of groove weld

the joint is solely the designer's responsibility and he cannot afford to have a loophole for later error. It is also a small shop indeed where the responsibilities and duties of layout and cutting of material, plate edge preparation, assembly and welding are not carried out by different individuals, if not in separate departments. Each step must be coordinated and it seems almost needless to point out that the blueprint is the ideal means of coordination.

But it is in the selection of the exact type of weld, with regard to its location, that some of the hard facts learned by the shop must be also known to the designer. This is as good a place as any to digress from our present consideration of joint and weld types to consider some of the economic and physical characteristics of this particular joint and group of weld types.

First: Weld metal, for all the economy in its over-all application when properly used, is a relatively expensive material. The cost we are interested in is not particularly the price per pound of electrode—even in the present day this represents only a small percentage of the cost of "deposited" metal. The exact cost of the latter varies widely and is a function of the material, the electrode size and deposition rate, the position in which the joint is welded, the rate paid the operator, the method of payment and perhaps several more factors. Under ideal conditions it may be as low as a dollar a pound in manual arc welding, while under adverse conditions it may be three or more times that. It therefore behooves the designer to use it with decent thrift—the minimum quantity to accomplish his purpose—and no more. This fact is not, of course, peculiar to the groove joint. It is equally true in every joint and weld, and indicates that we should not only use a minimum quantity of welding per joint, but a minimum of joints as well.

In plates $^1/_4$ thick for example, a root opening of $^1/_8$ in. permits a full penetration joint without beveling. In heavier plates, the edges must be beveled to permit good fusion for the full thickness of the plate, and an included angle of 60° is commonly used. As the plate becomes thicker, this angle results in an unnecessarily wide opening at the top or surface, yet the angle is still needed at the root. The J-groove provides this and reduces the amount of weld metal—but at greater expense, as a rule, in edge preparation. The point of minimum over-all cost or maximum return may well vary for different plants, obviously; it is enough for our purpose to point out the principle.

Again, take the case of the groove weld beveled from both sides. If the weld is, or can be made, easily accessible from both sides it will be noted that measurably less weld metal is required by the double-V than the single-V weld. True, this means of reduction results in somewhat greater cost in plate edge preparation and involves positioning—again, a matter to be analyzed for each individual case in the light of the plant's known cost.

Second: Aside from the direct cost of deposited metal, there are other considerations of the weld that

affect the choice of weld type, and the placement and extent of welding. The whole family of welding processes involve heat, and in considerable quantities and with high localized temperatures. Practically all of the metals we deal with expand with heat, enter a plastic stage, take localized changes of shape and then shrink on cooling. The result is that after welding we have changes in dimension (shrinkage), changes in shape (distortion) and in addition considerable residual stress. These are not new phenomena—and they are not peculiar to welding. The use of heat to assist in shaping metal to our needs is as old as recorded history and shrinkage, distortion and residual stresses have been with us since the first metal worker put his iron in a fire.

Figure 4 illustrates the phenomena in a single-V butt weld. It can be stated categorically that these changes are difficult to prevent. We can anticipate them; allowance can be made if necessary to end up with the over-all dimension, and the plates may be assembled at a slight angle to compensate for the angular distortion. These are shop functions but the designer must make them possible—or eliminate the need for such precautions by the choice of location or modification of the joint. Perhaps the joint can be so located or made in a sequence that the shrinkage does not matter, and by using a double-V in place of the single, the forces causing angular distortion are balanced. In the weldment as a whole, it may be possible to balance the longitudinal shrinkage of this weld by artful location of a similar joint on the opposite side.

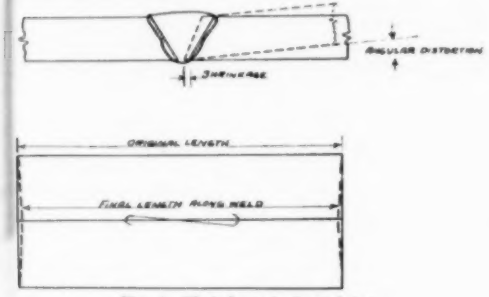

Fig. 4 Shrinkage in butt joints

The next joint to be considered, and almost as useful to the welded design, is the tee. The intersection of two planes, as in the case of web stiffeners, framing members on flat plate and a host of others is common, and again, the fusion weld provides an ideal connection. Ideal because no clips or connecting links need be used, and because any degree of strength (efficiency) can be obtained. In various combinations it permits material to be put, simply and effectively, exactly where it is needed.

As stated, the connection may be easily varied to give any efficiency desired or required. A minimum of preparation is required, nothing more than a reasonable fit to the passing plate, if fillet welds are used (Fig. 5). This leaves, of course, an unwelded section under the

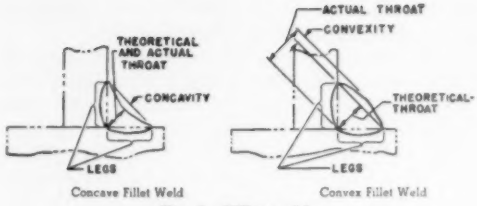

Fig. 5 Fillet welds

stem of the tee. In cases where the loading is in impact or repeated stress, this is not good, but in such cases beveling the item in a manner similar to one side of the butt joints just discussed permits full fusion (100% penetration) and provides a joint suitable for any loading. For static loading, full efficiency either in tension or shear is quite easily obtained by the simple joint and fillet welds. In mild steel, most low alloys and on many other materials, full efficiency is obtained with fillet sizes—measured by the "leg" dimension—considerably less than the thinner of the two parts being joined, when double fillets are employed. The throat section is the measure of strength, but since this is relatively difficult to measure accurately, we use leg size and the plane of failure is therefore $2 \times 0.707 \times$ leg $\times$ length, or per unit length is 1.4 times the leg dimension. This, of course, assumes the common 45° fillet weld, neither concave nor overly convex.

The concave fillet weld is not to be scorned by any means. It must be given its proper throat value and one difficulty is defining this since the toe of the fillet is now asymptotic and "washes out," providing no means of leg measurement. This is its virtue, giving a smoother flow to stress lines and avoiding a possible stress-raiser. Conversely, the "reinforced" or overly convex fillet defeats its own ends and may actually weaken the assembly by "notch-effect."

Less than full efficiency is easily obtained, obviously, by diminishing the size of the fillet welds. When the smallest practicable continuous fillets are still over strength, or for other reasons a continuous weld is not desired, intermittent welding provides a most satisfactory solution. While the author was, for a long time, an advocate of small continuous fillets rather than intermittent welding as means of reducing warping in well-framed flat plating, I have since become convinced that the intermittent weld is more effective. These remarks are emphasized because T-joints, particularly in stiffening members, are too easy to overweld—and nowhere else does overwelding create more trouble.

The remarks about weld metal cost, distortion and shrinkage are just as true in this joint as in the butt, with distortion perhaps a bit more the prime difficulty. Figure 6 illustrates the results of weld metal shrinkage, and Fig. 7 is intended to emphasize the result in panel stiffening of large flat areas—the pillow effect due to shrinkage in the length of such welds. There is much which the shop can do to minimize this distortion, but they are assisted materially if the designer does

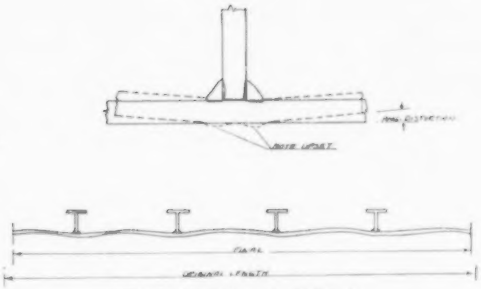

Fig. 6 Shrinkage in T-joints

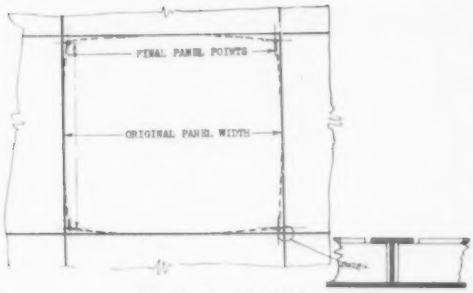

Fig. 7 Panel shrinkage

the one thing within his power on this joint, namely, the use of the minimum size weld to meet the required strength.

Third in importance, probably, is the lap joint. In arc or gas welding, the joint is welded by fillet welds. In this method of welding it might seem, at first glance, to have little advantage over riveting in structural work, at least, but the lap cannot be discounted entirely even if it does not have the weight advantage of the butt. It is a simple joint in preparation (frequently none) and requires practically no fitting. There is a great deal more allowance—"come and go." As a result it is frequently used where close tolerances in root openings would be difficult to predict or control. In thinner sections, it is far easier to weld than a butt, unless the latter is backed up. And lastly, it still has a weight advantage over the riveted joint, 100% efficiency is practicable and is obtained with less lap than would be required for one row of rivets with an efficiency of something like 74%.

In spot and seam welding we have no alternative to the lap joint. The analogy between the spot weld slug and the rivet require the same type of joint. But here the analogy ends. The designer does not have to worry about net section for tearing or bearing pressures and edge distance as in the case where holes are punched or drilled. He is limited solely by a lap width for his electrodes so that welding conditions promote the formation of a sound slug without excessive spitting, and the provision of sufficient spots to obtain the strength required. In the field where resistance welding presently finds its greatest application—sheet metal—the use of the small lap joint required by spot or seam welding presents no great handicap to charge against the economy of the process.

The corner joint is a sort of hybrid—one once graphically, if not accurately, described as a "right-angled butt." Most of the previous remarks about butt joints apply. While the matter will be covered more fully a little later, it should be pointed out here that this joint can, in many cases, be avoided by bending or flanging. When equipment to do so is available, and equal thicknesses are involved, it is usually far more economical to do so, with admittedly a smoother and more eye-pleasing result.

For the sake of completeness, the edge weld is also shown. Its use is relatively small and then generally confined to very thin materials.

Accessibility

In the foregoing discussion of the processes and joints available to the designer, we have actually covered a number of the most important considerations, but by no means all. Proper joint preparation—bevel, root opening and all such details—facilitate fusion and a sound weld, but are wholly lost if the joint as a whole is not accessible to the welder and his tools, see Fig. 8. It is nearly impossible to cover this point with rules, clearance dimensions or similar instructions without unduly restricting work. A welder can, if need be, accomplish some extremely difficult feats, if his electrode angle can be maintained together with adequate visibility. Too many good gas welding jobs have been done with a mirror, and arc work in places where but a few inches of electrode could be deposited with an 18-in. electrode. It is impossible, however, to play billiards with weld metal. Cushion shots are out, and the tricks to accomplish difficult jobs are costly in man-hours. In the last analysis, the designer should have had enough opportunity for shop observation to visualize the problem of actually making the weld. The greater the accessibility, the fewer the man-hours. In the case of resistance welding, the clearances and limitations of the machines available are far easier to establish, and must be available to the designer. One of the best devices I have ever seen in this regard consisted of small metal patterns made to a convenient scale which clearly indicated the exact shapes and size of various arms, electrode holders, etc., available, and by which any joint could readily be checked.

Accessibility can frequently be improved, and shop production simultaneously increased by the designer's consideration of subassembly possibilities. In more complex weldments, or in large and bulky assemblies, there is real economy in keeping most of the work in easily handled subassemblies, making the final joining of these as simple as possible. This means the elimination of irregular intersections, and hard-to-fit joints in final assembly. In structures, it simply means as much work as possible in the shop and a minimum in erection in the field. There is also a definite gain in dimension and distortion control since the final assembly joints can

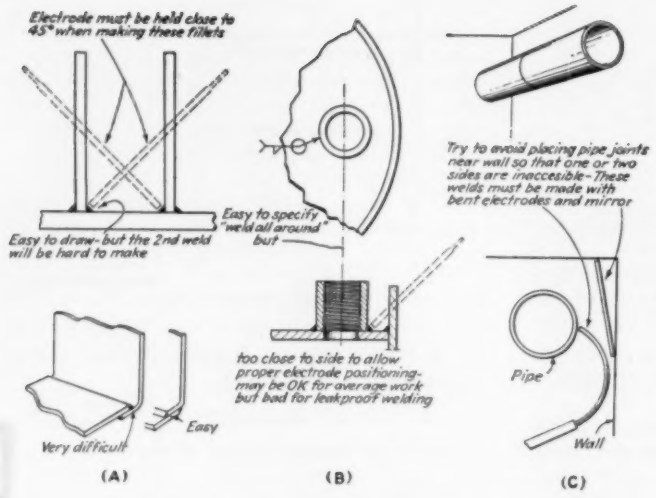
Electrode must be held close to 45° when making these fillets
Easy to draw- but the 2nd weld will be hard to make
Easy to specify "weld all around" but
too close to side to allow proper electrode positioning- may be OK for average work but bad for leakproof welding
Very difficult
Easy
(A)
(B)
Try to avoid placing pipe joints near wall so that one or two sides are inaccesible- These welds must be made with bent electrodes and mirror
Pipe
Wall
(C)

Fig. 8 Cost of welding is increased when welds are specified in locations where they will be difficult to make. Allowance must be made for room in which to manipulate electrode at the proper angle. (From "21 Ways to Lower Arcwelding Costs," by Robert Wilson, Lincoln Electric Co., in Iron Age, for Oct. 6, 1949)

frequently be cut in and prepared for welding after the bulk of shrinkage changes have occurred.

Positioning equipment, when available and when the weldment is within its capacity, removes most of the extra cost of what would otherwise be vertical or overhead work. Weld metal deposited in these positions costs 50% or more than down-hand, requires higher skill and in most cases will have a less attractive finish. Even the best positioning machine or table, however, will only present five sides of a cube to the welder and much of its value will be lost if the weldment must be detached and repositioned several times. Large weldments, elements of structure, etc., can frequently be positioned by comparatively simple devices if joints are so designed or located that only revolving on one axis is required. Lastly, the shop may find, on analysis, that the additional cost of an overhead or vertical weld, perhaps only a small percentage of a job, does not justify the cost of positioning.

Material

Some thought must be given to scrap losses, the degree of cutting and fitting required and the economical ordering of stock material. Generally speaking, the elimination of as many joints as possible will reduce the degree of cutting edge preparation, and simplify the ordering of stock. On the other hand, cutouts for forming may increase scrap. High scrap loss may result in over-all economy, if welding and fitting labor is thus reduced. While we stressed, as one of the major advantages of welding, the extensive use of basic materials, meaning plate, shapes, tubes and bars, the designer once deep in his problem should never lose sight of the economy, in many shapes and forms, of the casting or the forging. Both may well be incorporated in a design otherwise largely of welded plate. It requires selection of weldable material but provides, in many cases, the most economical answer. By the same token, some of the problems of a large and complicated casting are best solved by breaking into several smaller and easily made castings, welded together to form a more economical finished unit. There is always the need for analysis and the exercise of ingenuity.

Design For Welding

One brief reference has been made to notch effect. As in all design work, points of stress concentration must be watched in any important weldment. Those arising from notch effect are particularly insidious and, in the case of large structures, most important due to the monolithic nature of an all-welded design.

We seem to have arrived at a point where we can summarize.

First, what we might call the fundamental rules upon which sound welding design must be based:

1. Approach the redesign of previously cast, forged or riveted items as a new design, on the basis of the functions to be performed.

2. Use materials where possible which require the least in welding precautions and least skill.

3. Welding is a means to an end, but to the designer not an end in itself. Avoid extra and unnecessary joints by flanging, bending or rolling, the use of standard sections, stampings, small castings or forgings wherever necessary or advisable.

4. At least mentally review all the welding processes available and applicable to various parts of the design on the basis of material, thickness, form and quantity.

5. Estimate the stress patterns under load with respect to stress concentration and examine the design for the possibility of notches.

Second, we have discussed in some detail a number of the factors or considerations which the designer should keep in mind as his design work proceeds. These are factors rather than rules, since in most cases not all are possible of attainment except in degree and some, if followed blindly, lead to conflicting answers. It there-

fore remains for the designer to weigh these factors, choosing the course giving the best answer for his particular problem. It is not surprising that these factors are concerned with the "where" and the "what" of joints.

Locate joints with the following in mind:

(*a*) Economical layout and preparation, low scrap loss in material and extras in special sizes or forms.
(*b*) Accessibility of joint.
(*c*) The possibilities of subassembly.
(*d*) The position in which weld will be made, with due regard to positioning practice on handling equipment available in shop.
(*e*) Ease of assembly, with simplicity in jigs or fixtures.
(*f*) Appearance.
(*g*) Shrinkage and distortion.

Choose joint types with the following in mind:

(*a*) A type adequate or suitable for the nature of load.
(*b*) Minimum use of deposited metal.
(*c*) Least cost of joint preparation.
(*d*) Ease in fit-up and maximum tolerance, without undue increase in deposited metal.

Examples

Design examples can be discussed *ad infinitum* and, in fact, to demonstrate each rule and factor to be considered would require a number beyond the limits here imposed in time and space. Since welding invades all fields of design, it is likewise impracticable to deal with typical weldments in each field. An arbitrary choice has therefore been made to use the development of a welded valve manifold, since a majority of the fundamentals are demonstrated in a weldment common to many industrial applications.

Wherever liquids must be taken from a number of sources, or directed to a number of end points by common pumping equipment, there is need for individual valve control and some sort of a header or manifold.

For space saving, and in many cases where space is not a factor, the two functions are combined by placing a series of valves in a common body.

For many years these have been cast in the various materials required by pressure and service. Here we consider the cast steel type used in a wide range of sizes and multiplicity of valves. A great deal of core work is necessarily involved, together with internal separators, creating serious difficulty in tightness. In fact, practically every casting leaked on initial test and required corrective work at points very difficult to reach. In addition, wall thicknesses adequate to permit metal flow to all parts of the casting made the overall weight excessive.

A number of designs, practically duplicating the cast body, were rejected. While there was some weight saving accomplished, it was usually at the expense of high cost and in most designs involved difficult internal welding which had little advantage over repair welding on the original castings. The problem was then attacked from the standpoint of function, and the most direct way of accomplishing those functions.

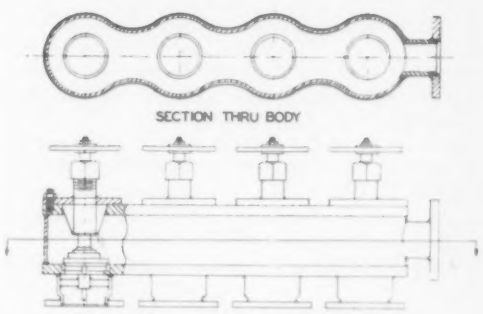

Fig. 9 Low-pressure manifold design

Basically, what is required is a valve deck, providing for the valve seats of any required type and a means of attaching the pipe leads to that deck. Above the valve deck there must be a common chamber with means to connect to the other pipe line. Finally, means must be provided for access to the valve deck, for bonnets and valve-operating gear.

The final and basic design is shown in Fig. 9. A rolled plate, thick enough to permit valve seat inserts, forms the valve deck. A reducing nipple and flange is very simply welded to the under side of this plate to provide for the attaching lines. The common chamber could be a rectangular box, but would have required heavy or ribbed sides to take pressure. Cutting the valve deck to the shape shown accomplished several things. First, the surplus weight of the valve deck was reduced. Second, the curved sides of the chamber automatically stiffened these sides and permitted very thin plates. This in turn permitted the omission of internal root welding, except in the largest sizes where the openings give adequate access. There was little increase in the scrap loss due to the shape adopted, as manifolds of a common size could be "nested" in the layout.

The curved sides necessitated pressing the relative light sides from strip on narrow plates. It was, however, necessary only to make simple dies of one complete cycle of corrugation, merely taking additional bites if the manifold had three, four, five or a greater number of valves.

The bonnet deck was also cut from heavy plate, approximating the thickness of the deck. This "balanced" the shrinkage of welding the sides, and provided for any desired gear or bonnet assembly, together with packing. The one shown is a small size. Larger valves require bonnets, suitable gland packing and adequate guides and supports for the valve-operating spindles.

The assembly "jigs" consist only of the simplest sort of spacers, permitting ready assembly and tacking. Once tacked, all welding is accessible with the manifold

secured, bonnet deck down, to a positioning table. As stated, only the very largest sizes required internal welding at the weld roots and the openings for valve gear in these sizes were adequate to give good accessibility.

In this case all the goals of redesign were achieved: (1) leakers were eliminated, (2) weight and space were reduced, (3) over-all time, particularly in case of plan changes, was greatly reduced and flexibility in the shop similarly improved and (4) cost was reduced.

Born as a means of breaking a bottleneck in wartime ship production, it is now in commercial production and obtaining wide acceptance.

Similar analysis of a wide variety of machines, structures, appliances, vehicles—every item in the field of metal fabrication—is almost sure to reveal a simple, functional solution through the medium of some form of welding. The requirements are simply a sound engineering approach, a working knowledge of the welding processes and some original thought—surely a challenge to the engineer-designer who is not restricted to the past and a handbook.

Welded Deck Girder Highway Bridge

Discussion by Gordon Cape

Not only has the author presented a paper which contains unusual and informative data, but has also made a valuable contribution to welding in heavy industry. It is particularly interesting to some of us in Canada who have been producing the same type of bridge since 1936. A total of 15 welded plate-girder bridges have been completed including structures as long as 1550 ft., with span lengths up to 180 ft. Certain features in the design, fabrication and erection of these bridges are at variance with the bridge constructed in Iowa, and it is thought that some comments on these differences might be of value.

The web thickness of Canadian bridges in general is of considerable interest. It was originally felt that specifications governing the height-to-thickness ratio of girder webs were too severe when compared with existing structures. A considerable amount of evidence was obtained which showed that the web plates in some old bridges had been designed with much greater h/t ratios. Also the webs of many older bridges, carrying full load, had over the years corroded to such an extent that a penknife could be pushed through them.

Consequently, since better maintenance is assumed than in years gone by, the first welded bridges built in Canada (with a maximum depth of girder of 7 ft.) were made with a minimum web thickness which was considered reasonable for fabrication, namely $^3/_8$ in. The performance of these bridges was studied and observed to be satisfactory, with the result that a $^3/_8$-in. web thickness has been maintained on increasing heights of girders up to 12 ft.

Experience in fabricating the Iowa bridge has led the designer to believe that a $^5/_8$-in. web thickness would be preferable to $^1/_2$ in., in order to offset the buckling tendencies in the webs. It has been our experience, however, that although $^3/_8$-in. webs also may buckle somewhat, due to welding, the buckles will not necessarily be more severe than when thicker webs are used, and they can be easily rectified or prevented by appropriate welding procedures at no extra expense in cost or time. Except at the piers, the girders of the Canadian bridges are designed with stiffeners on the inside surfaces only, so that below the sidewalk brackets, the webs present a smooth unbroken appearance from pier to pier. Neither excessive buckling between stiffeners nor sharp kinking at the stiffeners occurs with the welding procedure used. Fabrication is broken down into four distinct stages as follows:

Stage 1. The first stage consists of the welding of the web-plate splices, then marking and trimming of the edges of the web plate to proper contour by flame cutting, followed by the assembly of the angle stiffeners with their toes adjoining the web, but having three or four short pieces of 16-gage soft iron wire spacers placed transversely to separate the joint. At this time, the stiffeners are welded to the webs for a distance of only 15 in. inward from the edges of the web. The stiffeners beneath floor-beam ends do not run the full height of the girder, and are consequently welded at one end only at this time.

Stage 2. The next stage consists of assembling and welding flange plates to webs. The method of assembling consists of holding the flanges and webs together with yokes and long bolts, the webs being located on the center lines of the flanges by means of guide washers tack welded on edge, to the flanges only, on either side of the web. The girders are placed in a vertical position and welding proceeds from midlength toward the ends, all welds being completed in turn to their full size. The guide washers permit differential movement between the web and flanges without restraint. The flange-to-web welds are made in increments of about 30 in. These made are $^3/_8$-in.

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Paper by Ned L. Ashton was published in THE WELDING JOURNAL, September 1949, pp. 832-840.

fillets made of three beads in two layers. The welding operators work in pairs, one on either side of the web, and the girder is inverted two or three times during this stage, depending upon its length, so that the welding on one flange will not advance so far beyond that on the other as to result in permanent bowing.

Stage 3. At the beginning of this stage, which consists of the finish welding of stiffeners to web plates, measurements would disclose that the webs were decidedly buckled, chiefly due to the contraction of the longitudinal welds, amounting to about $^1/_8$ in. in 70 ft. The unwelded mid-height portion of each stiffener is then intermittently welded using $^1/_4$-in. fillet weld increments of 2 in. spaced 12 in. apart, which is sufficient to meet the design requirements.

After this intermittent welding, some buckling still remains in the web, the magnitude of which may vary from panel to panel. Starting at mid-height of the web, the spaces between the weld increments on the stiffeners are then filled in until sufficient additional welding has been done to pull most of the buckle out leaving $^1/_4$ in. maximum. Since the entire removal of a buckle might induce rather high-residual stress, it is felt safer to permit a slight deformation to remain.

To eliminate the sharp kinking which usually occurs in a plate opposite stiffener welds, the soft iron wire spacers mentioned previously, and also wedge-jacks are used at approximately 2-ft. spacing to pre-spring the web on either side of the stiffeners in such a direction as to counteract the angular distortion or bending that normally results from the transverse contraction of the fillet welds. The soft iron spacers permit relatively free contraction across the joint.

Upon the completion of Stage 3 there is little if any buckling or kinking of the webs. The prescribed amount of camber for the girder is maintained within a tolerance of plus or minus $^1/_8$ in. Angular deformation of the flanges from the horizontal (sometimes referred to as "cupping") is held to a maximum of $^1/_8$ in. in 12. The total longitudinal contraction in the length of the girder at this time amounts to $^3/_8$ in. maximum in 70 ft.

Stage 4. The last stage of the shop fabrication consists of marking, trimming by flame cutting and template drilling of the ends of the girders for field splices.

FIELD ERECTION

The field erection procedures require that field splices be designed for a temporary erection load of a traveling derrick and a full-length girder. Consequently, field bolted and drifted splice-plates are used on both flanges and webs to carry the temporary erection load. No welding is done on the girder splices until the erection has been completed for two spans ahead.

The sequence of field welding employed on the Iowa bridge is the same as that which was first used for the field welding of bridges in Canada. It proved to be satisfactory when the heights of web were not in excess of 4 ft. However, on later bridges with deep girders, it was found that this procedure resulted in excessive buckling of the webs.

The revised sequence for making the welded field splices of the girders is as follows:

1. Weld the top and bottom flanges for $^1/_3$ to $^1/_2$ of their thickness. The joints are open-gap butt welds with backing bars, made in the downhand or flat position. It has been found that these flange welds contract a total of $^5/_{32}$ in. The amount of welding performed on the flanges at this time is intended to result in a partial contraction of the joint to such an extent that the contraction caused by subsequent welding on the flanges will be about the same as that which occurs in the web plate when welded.

2. Weld 12 to 15 in. at the top and bottom of the web splice, for the full thickness. These portions of the weld will then be under tension due to the weld shrinkage.

3. Complete the welding of the top and bottom flange joints. This reduces the tension in the web and results in some buckling.

4. Complete the welding of the remaining mid-height portion of the web joint. The shrinkage of this welding will remove the buckling in the web which occurred during the previous operation.

It is realized that this procedure does not entirely eliminate the residual stress (a thing which would be impossible of accomplishment), but it does reduce the buckling to a negligible amount. When the above-mentioned procedures have been used, no cracking has been experienced, even when the welds have been made under fairly cold temperature conditions.

New Developments in Oxyacetylene Cutting Machines

Flame cutting machines are now found in the production line. Special purpose and standard machines are described and their uses indicated

by W. Begerow and A. H. Yoch

WITH development work relating to torch-cutting machines practically held at a standstill during the war years, it is only natural that activity in this branch of the industry is accelerated in the post-war years.

As an outgrowth of the many production oxyacetylene-cutting operations during the war there is an ever-increasing demand on the part of production engineers to employ flame cutting.

With the wider use of welding in fabrication and the welding of similar parts in relatively large quantities greater and more exacting demands are made by users in this field, some of which are as follows:

1. Greater dimensional accuracy in the cut piece.
2. Use of multiple torches to cut a greater number of pieces in one pass.
3. Stack cutting with one or more torches.
4. Remote control of torches.
5. Lower costs in the preparation of the template in shape cutting.
6. Decrease in time lag between template preparation and cutting operation.

The flame-cutting machine not too many years ago was a machine at the end of the shop used only occasionally to cut some particular shape when required.

In contrast to this it is not uncommon to see flame-cutting machines in the production line cutting thousands of pieces on a single order.

Based on experience gained through the operation of standard machines, special-purpose and very often single-operation machines are constantly being developed and constructed. While many single-purpose cutting machines are designed and constructed by equipment manufacturers there are also many cutting machines built by the ultimate user. Very often such machines employ units and subassemblies of standard equipment arranged in a suitable manner for the specific operation at hand.

For the purpose of this paper we will separate the special-purpose flame-cutting machines from so-called standard machines. We will first describe special-purpose machines.

Figure 1 shows a machine which was built for contour beveling.

By synchronizing the rotation of the tracing device and the torch, it is possible to cut bevels on irregular outlines. In this instance the torch is positioned as shown because the pieces to be cut are of semicircular cross section. It should be noted that standard equipment is used except for the portion required to synchronize the rotation of the tracer and torch.

Figure 2 illustrates a close-up of the tracer drive and rotating medium.

This machine, Fig. 3, was developed to cut openings in motor frames. It will cut four openings simultaneously. The operation of this machine is very unusual. The torches, torch arms and the square bar to which they are attached are counter-weighted. The dead weight counter-weight moves up and down in the tube shown at the top left. The square tube moves up and down through the housing fitted with ball bearings which guide the tube. The housing through which the tube moves may also rotate as it is fitted with ball bearings at the top and bottom. The raising-lowering and rotation of the torches is obtained by the magnetic roller driving the cam or template mounted to the square tube.

The torches may be moved manually in their torch holders so that various diameters of motor frames may be cut.

The torch arms may be prepositioned around the periphery of the frame as openings are not always equally spaced.

The gases are controlled by means of solenoid valves. The speed of cutting is controlled by means of a governor controlled motor.

Figure 4 shows a machine designed for steel mill use. The shields are removed to better show the machine

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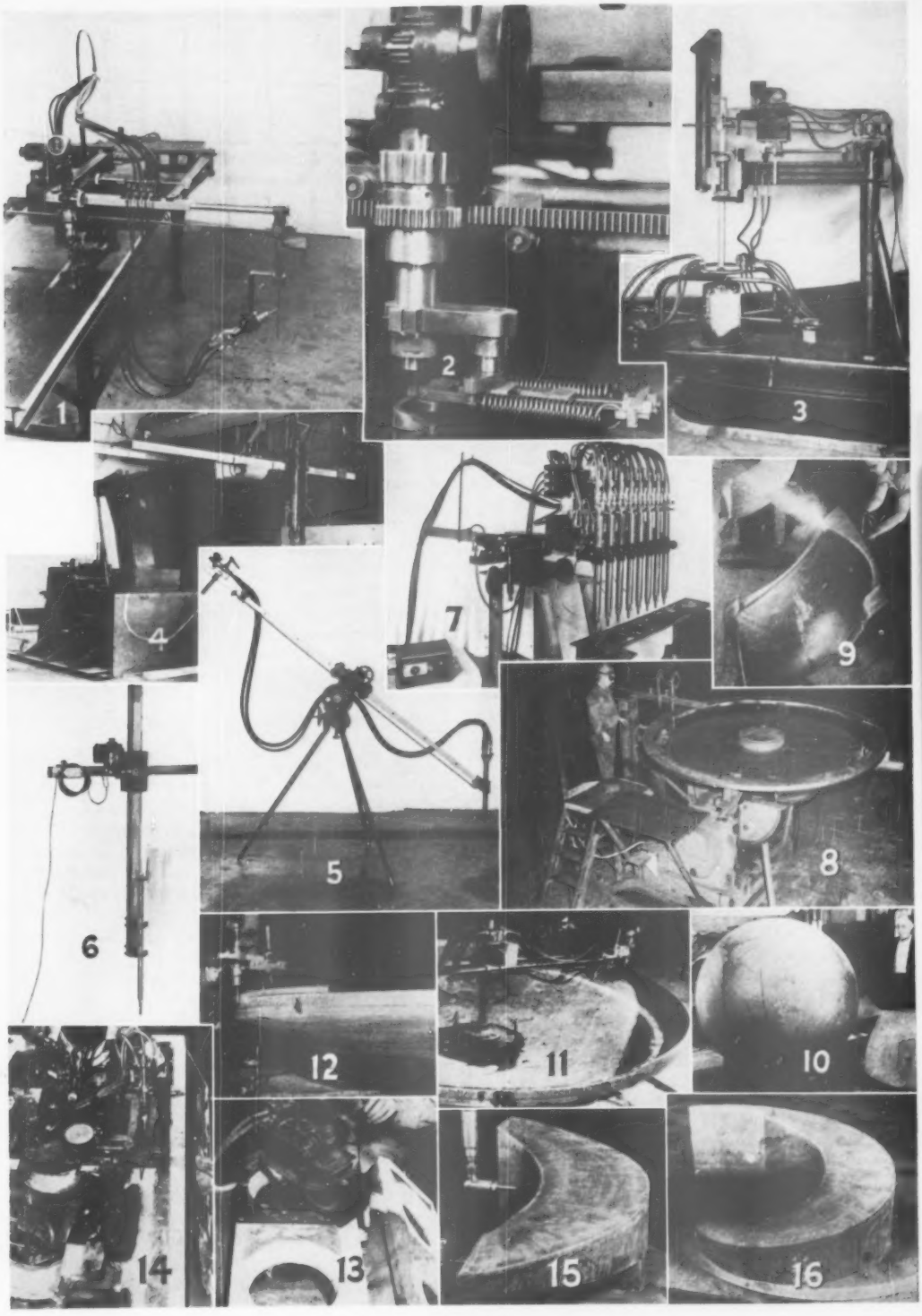


Figures 1–16

members. It is particularly suitable for cutting relatively large cross sections at elevated temperatures. Single or multiple torches may be used. The operating principle of this machine is quite unique as the torch will follow any contour under it automatically.

The horizontal travel of the torch is obtained by the vertical member pivoting on a pair of sealed roller bearings. The vertical travel of the torch is obtained by pivoting the horizontal arm. Each of these motions is actuated by separate motors. The automatic contour following of the torch is obtained by an electronic probe adjacent to the torch. As the torch progresses horizontally over the piece being cut the electronic probe imparts a signal to the raise and lowering motor so that a very exact separation between the torch and the surface of the work is maintained. This machine is operated from a control desk which may be located remote from the machine.

Figure 5 shows a semiportable machine designed to cut off risers from steel castings in steel foundries. With this machine the risers may be cut smoother, closer and at higher temperatures than can be cut by hand.

The tripod on which the machine is mounted is positioned adjacent to the casting. The square tube on which the torch is mounted moves through the roller housing by means of a rack and pinion. The square tube may be adjusted to any desired angle by means of the self-locking worm and worm gear. The entire unit may be pivoted in the same manner as a photographer's camera. The gas controls may be attached to the square tube or held in the hand of the operator. The torch may be raised or lowered by a hand wheel located on the end of the square tube opposite the torch. The travel of the tube may be either motor driven or manually operated.

The tripod is of rugged construction with adjustable legs. Large hooks are provided so that the unit may be lifted by means of a crane.

Figure 6 shows a motor-driven torch raising and lowering device. This unit was designed to provide a vertical travel of 6 ft. This exceedingly large travel was necessary as the unit is used in connection with skull cutting. By means of a motor-driven rack and pinion drive the torch is raised or lowered by means of a momentary contact switch actuated at the operator's station. The unit is driven by a governor controlled motor making it possible to vary the speed of raising and lowering.

Figure 7 shows a machine designed and built to flame cut slots in the ends of mine anchor bolts. Eight bolts are cut at one time. The torches, gas manifolds and pilot lights are attached to one end of a 3-in. square tubular bar. The bar by means of a motor-driven pinion which engages a rack attached to the bar moves the torches over the bolts to be cut. The bar is guided by the roller housing through which it moves. The length of travel or depth of slot is determined by means of an adjustable stop attached to the bar. A torque or over running coupling is used between the motor shaft and the gear train to prevent jamming. The gases are controlled by solenoid valves. A feature of this machine is the use of solenoid valves attached directly to the torch. Because the cut is terminated within the cut piece, bleeding of the cutting oxygen from the manifold after the valves are shut-off is detrimental to the cut. For this reason the solenoid valves for the cutting oxygen are placed as far down stream as possible which for all practical purposes is at the torch. This machine is operated from a control unit detached from the machine so that it can be located at the best vantage point.

A special circular ring-cutting machine for simultaneous cutting of the outside and inside diameters of a circular ring, is shown in Fig. 8. The diameters are approximately 108 in. O.D. and 94 in. I.D. with a thickness of approximately 2 in.

The ring stock is held by means of a locating fixture affixed to a weld positioner which rotates the ring at a proper speed for flame cutting. Two standard machine-cutting torches and adjusting devices are mounted on a 3-in. sq. support bar which is pivoted to move out of the way to permit placing or removal of the work-piece.

Adjustable stops are used to permit location of torch assembly into positions for the cutting operation.

Figure 9 shows an arrangement of a cutting-machine for cutting $^5/_{16}$-in. thick dished sections; it consists of a standard portable straight line and circle cutting machine with a guide roller attachment to follow a circular track and guide strip.

The cutting torch unit is guided along the plate contour by means of a spring-loaded torch holder.

A number of jig locating devices are used to complete the four cuts. The completed sphere consisting of six flame-cut segments is shown in Fig. 10.

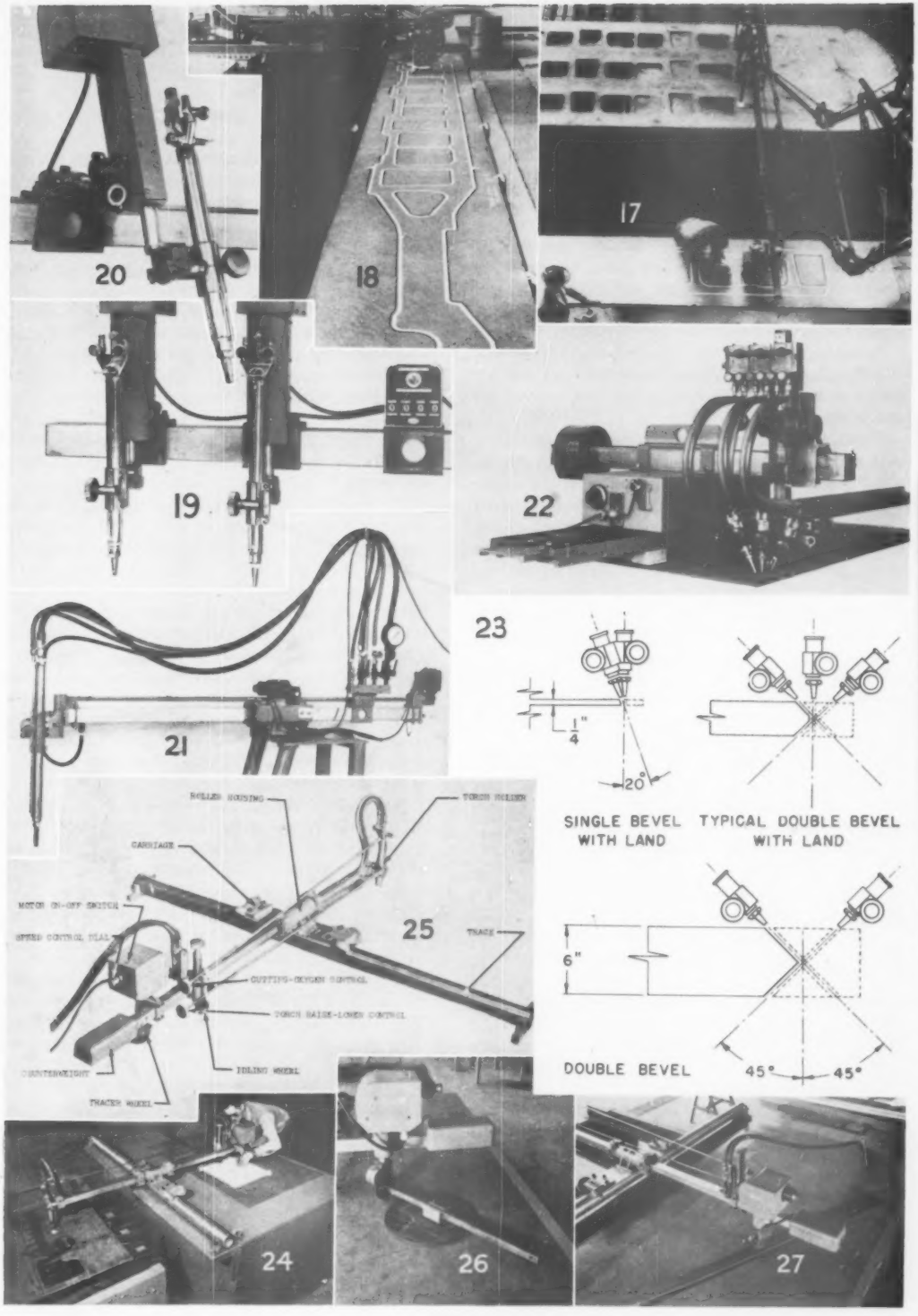
Figures 11 and 12 show a portable head-trimming machine with a range of 80 to 200 in. in diameter. The machine consists of an adjustable pedestal base and post which in turn supports an adjustable radial arm pivoted around the center support post.

To the end of the radial arm is affixed a variable speed magnetic drive unit which contacts the outer flange and uniformly guides the torch element along the proper contour making a straight cut or any desired bevel cut. The head being cut is $1^1/_4$ in. thick, 183 in. diameter and 28 in. deep.

Figure 13 is a special portable circle-cutting machine made up of certain standard parts with holding and locating fixtures for flame cutting or trimming the top and bottom openings for cylinder liners in a welded Diesel engine crank case.

The diameter is approximately 12 in. and thickness varies from approximately 2 to 3 in. depending upon the sizes of engine frames. The top and bottom opening can be cut using an extension spindle.

Figure 14 is a special portable shape-cutting machine using a formed template and guide device for cutting the connecting rod clearance on the bottom side of a welded Diesel engine crank case. A variable speed



Figures 17–27

motor drives a "V" belt arrangement with a latch to engage and move the cutting torch.

Figures 15 and 16 are examples of flame cutting done by means of a simple arrangement of standard machines, the motions of which are properly coordinated to form a helix or spiral cut.

A cylindrical section, 21 in. thick, 28 in. O.D. x 8 3/4 in. I.D. are cut by means of a standard shape-cutting machine. The cylinder is then placed upon a rotating device and a vertical straight-line machine affixed alongside. Proper coordination of speeds resulted in the production of the spiral cuts shown for the forming of a die for making spiral elevator conveyor flights.

Earlier in this paper the term "Standard Machines" was mentioned. "Standard Machines" means those machines manufactured in quantity and stocked for immediate use.

There is no doubt that in this group the outstanding postwar development is the "Electronic Tracing Device," Fig. 17. As is well known by now this device by means of a reflected light, obtained by projecting a small light spot on the template, will by means of photo-electric tubes automatically steer the tracing device along any template outlined. Substantial savings are effected in template preparation. In one shop a template which took a month to build for another method of tracing took only a week for the electronic tracer.

One of the outstanding applications of the electronic tracer to date is the multiple flame cutting of locomotive side frames. These side frames are made in three sizes, and at one time constituted the backbone of reconstruction of European railroads destroyed by the war. A number of these frames in fact were used on "Liberation"-type locomotives, delivered to the French National railroads.

As an indication of the sizes of the work the rolled plate on one size was 5 1/2 in. thick, 9 1/2 ft. wide, 40 ft. long and the frames were 5 1/2 in. thick, 2 ft. 7 1/2 in. wide and 38 ft. 10 1/2 in. long.

Figure 18 shows a close-up view of the electronic tracer and template. The template base consists of Masonite upon which is superimposed a white plastic strip tape glued to the Masonite.

The advantages of the electronic tracer and template are the rapidity with which a template can be built, also altered in shape or size if required.

The increasing use of multiple torches for shape cutting operations brings to the fore the demand for labor saving and easier means for torch raising and lowering. Figure 19 shows a pair of torches which may be raised or lowered by actuating momentary contact switches at the operator's station. Each torch may be raised or lowered individually or all torches may be raised or lowered simultaneously. This enables an operator to quickly raise all torches at the completion of a cut and also to lower the torches to just above the plate surface prior to and during cutting. Other features of this unit are that the unit may be so positioned that raising and lowering for beveling operations may be effected without producing steps in the cut. By means of an adapter the torch may be positioned for beveling in a plane perpendicular to that first shown (Fig. 20).

The motorized torch arm is a unit developed primarily for heavy-cutting operations, Fig. 21. It may be mounted on a fixed pedestal or on a carriage type of machine. The 3-in. square bar is moved through its roller housing by means of a motor-driven pinion engaging a rack attached to the bar. The torch is raised or lowered by means of the motor mounted on the end of the bar opposite to the torch. The torch may be positioned to any desired angle within limits without hindering the raising and lowering feature. The square bar is powered by a governor-controlled motor while the raising and lowering is accomplished by a constant-speed motor. Hand wheels may be substituted for the motor. Adapters that may be fitted to the torch holder make it possible to use various diameter torches.

The increased use of employing cutting torches to prepare the edges of plate for welding has brought the demand for a multibeveling unit such as is shown in Fig. 22. This unit may be used with a carriage-type machine or a shape-cutting machine of the pantograph type. With this unit bevels as small as a 20° bevel with land on 1/4-in. plate to 45° double bevel on 6-in. plate may be cut. The unit is capable of cutting single bevels, single bevels with land, double bevels and double bevels with land (see Fig. 23).

The three torches mounted on the cross arm which is attached to a square tube is free to float up and down as the adjustable contact wheel follows the undulations of the plate. The square tube is guided by the ball bearing roller housing. The torches may be quickly and easily preset to the desired angle. They may be accurately adjusted horizontally by means of the knobs at the ends of the cross slide. When proper setting is obtained the cross slides may be locked.

The torches may be raised or lowered within the torch holders by means of the hand wheels which project to the front and away from the heat.

The preheating flames are adjusted by the needle valves at the top of the unit and away from the heat. The cutting oxygen valves are also located at the top of the unit. Master shut-off cocks for the preheat gases eliminate the need for readjusting the preheat flames between cuts. That portion of the unit which moves through the roller housing is counter-balanced by means of a clock spring thus providing a smooth easy movement without jerks. The floating portion of the unit may be easily and quickly locked. This is necessary when approaching the end of a plate. It may also be locked in an elevated position to clear the work. The cross arm may be rotated so that bevels may be cut at any predetermined angle to be traced by the shape-cutting machine. A very desirable feature is the ability to microadjust the entire unit laterally so that a particular setting may be kept intact. Another very

desirable feature is to pivot the unit to a horizontal position so that the cutting tips may be readily serviced.

Figure 24 shows an accurate portable shape-cutting machine. Its construction is simple and rugged and with auxiliary equipment lends itself conveniently to cutting of straight lines and circles.

Figure 25 shows mounted at one end of an accurately ground and chrome plated square bar a cutting torch. At the opposite end of this bar is attached the familiar manual tracing device. The square tube moves through a housing fitted with ball bearings providing the longitudinal motion. This roller housing is mounted on a platform equipped with large ball bearings which roll along a round tube which is the track providing the lateral motion. The torch may be raised or lowered by means of a knob located at the operator's end of the bar. The cutting oxygen may be turned on and off by similar means. A caster and elevating device is provided to raise the tracing wheel above the table so that the template may be quickly and easily positioned in relation to the workpiece. A radius rod shown in Fig. 26 is provided for circle cutting and a grooved straight edge shown in Fig. 27 is provided for straight-line cutting. The cutting area of the machine is 32 in. wide by 56 in. long. By means of an auxiliary track the cutting area can be increased to 32 in. wide to 136 in. long and may be further increased in increments of 80 in. by adding additional lengths of track. The portability of the machine lends itself readily for use directly on the plate to be cut. This is an ideal machine for use by contractors on construction sites.

The authors of this paper feel that this material is a fair cross section of new developments of oxyacetylene cutting machine and cutting applications and hope that it may serve as thought starters for new applications in this field.

ACKNOWLEDGMENT

Mr. Yoch and Mr. Begerow want to take this opportunity to thank the Lukens Steel Co. and its divisions the By-Products Steel Co. and Lukenweld for the illustrations of machine shown in Figs. 9–18, inclusive.

Problems Associated with the Welding of Stainless Clad Steel

Discussion by A. L. Schaeffler

Mr. Arnold's paper is a welcomed contribution to the science of welding. We agree that there is a great need for airing the problems of welding clad steels and concur with his hope that his paper will be the impetus for more publications.

We have been conducting investigations in cooperation with L. W. Williams and L. K. Dawson of the Lukens Steel Corp. in attempting to solve some of the problems relating to the welding of clad steels. The problem described by Mr. Arnold was brought to our attention about a year ago and has been the subject of one of these investigations.

We would like to pursue Mr. Arnold's comment that it was most difficult to qualify welds made in the horizontal position. We assume that the trouble was weld metal fissuring. Any information or elaboration from Mr. Arnold on why the horizontal position of welding causes most trouble is welcomed.

We believe that the principal sources of difficulty are (1) the great transverse *lateral* restraint resulting from the thickness of plate being welded, and (2) the great transverse *angular* restraint resulting from the geometry of the vessel. The plate thickness is mentioned by Mr. Arnold as one of the factors causing trouble. Figure 1 is presented to illustrate our contention that weld fissuring is not associated only with the horizontal position of welding. Weld No. 2 was

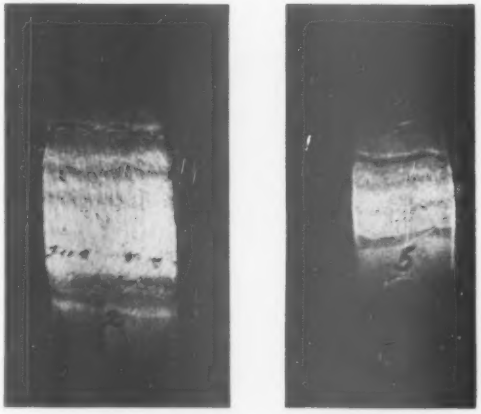


Fig. 1 Bend tests of simulated two-layer clad weld made with 0.09 C, 25–20 electrodes in 1 1/2-in. mild steel plate (No. 2) and in 1/2-in. mild steel plate (No. 5), in the downhand position

The great restraint offered by the 1 1/2-in. thick material is responsible for the weld-metal fissuring

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Paper by Perry C. Arnold was published in THE WELDING JOURNAL, October 1949.

Table 1

Size, in.	Electrode*	Chemical Analysis						
		C	Mn	Si	S	P	Cr	Ni
1/8	25–20	0.090	1.62	0.48	0.007	0.020	25.52	21.36
1/8	High-C 25–20	0.17	....	0.54	0.014	0.020	26.89	22.56
1/8	29–9	0.108	1.38	0.36	0.006	0.022	27.02	9.36
5/32	19–9	0.054	1.69	0.37	0.011	0.020	20.38	10.39
5/32	27–13	.....	.....	.....	.....	.....	26.83	12.73

* All electrodes have pure lime (no titania) coatings.

made in 1 1/2-in. thick mild steel and No. 5 in 1/2-in. mild steel, both in the downhand position using a 1/8-in. diameter pure lime coated 25–20 electrode. (See Table 1 for the chemistry of the electrode used.) Bend test specimens of approximately the same dimensions were cut from the two plates and bent. Fissures are visible in No. 2, but none was present in No. 5. Using a 10-power magnifier the fissures were visible in No. 2 even before bending. Of course, this is not conclusive proof, but it supports our observations that the greater the thickness of plate or the greater the lateral and angular restraints even in thinner plate, the greater is the tendency for weld fissuring. This problem has been discussed in various papers.[1–4] We also observe that when making all-weld-metal tensile specimens, using an electrode that is susceptible to fissuring, no fissures or cracks appear until about the fourth layer of the deposit. The initial layers are under angular restraint only. The subsequent layers are under angular and also lateral restraint; the lateral restraint increasing as the number of layers increases. Upon examining the all-weld-metal tensile specimen after it has been pulled, if fissures are present at all they will be found on the side of the specimen closest to the top of the weld.

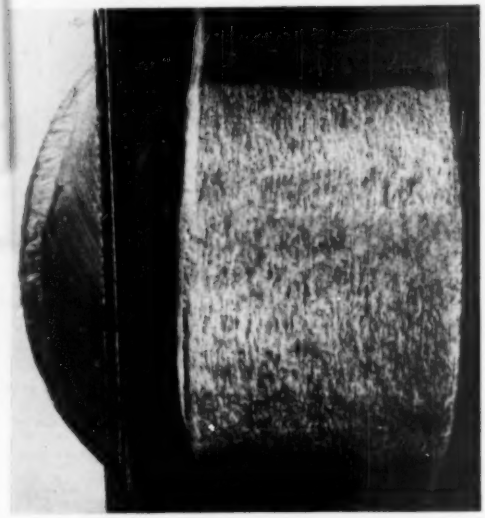

Fig. 2 Bend test of simulated two-layer clad weld made with 0.17 C, 25–20 electrodes in 3/4-in. mild-steel plate in the horizontal position

The higher carbon changes the character of the austenitic weld deposit and eliminates fissuring

Because the fundamental factor governing the failure to obtain adequate elongation was weld-metal fissuring, we decided to investigate that aspect only.

Fully austenitic weld metals like 25–20 exhibit fissuring or cracking tendencies under relatively few welding conditions. In those extreme cases, fissuring or hot cracking can be eliminated by modifying the chemistry of the weld metal. One method is to increase the carbon content of a 25–20 deposit from its usual 0.09% to between 0.15 and 0.20% depending on the silicon content. This weld deposit will still be fully austenitic. The other method is to increase the chromium and/or lower the nickel to produce a partially ferritic deposit. Such a deposit is highly resistant to fissuring.

Figure 2 illustrates the beneficial effect of increasing the carbon content to 0.17% in a 25–20 deposit. The weld was made in a groove in 3/4-in. mild steel in the horizontal position. The specimen has elongated 31% in the as-welded condition. This method may not be practical, however, because of restrictions which may limit the carbon content of the surface bead.

Figure 3 illustrates that fissure-free weld metal can also be had by introducing ferrite. The beads of the first layer were deposited with a 29–9 electrode and the second layer with a 19–9 electrode. The weld was made in 3/4-in. mild steel plate in the horizontal position. The

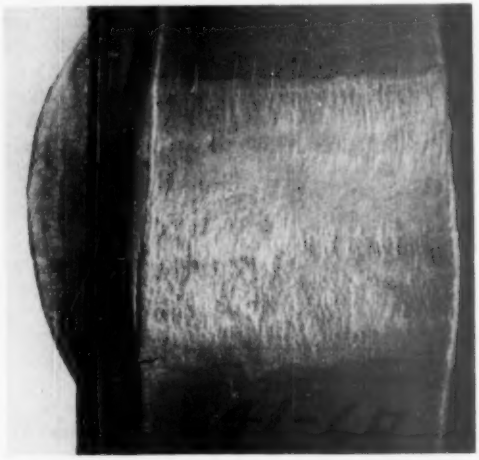

Fig. 3 Bend test of simulated two-layer clad weld made with 29–9 electrodes in first layer and 19–9 electrodes in second layer in 3/4-in. mild-steel plate in the horizontal position

The ferrite constituent present in the microstructure of this deposit prevents fissuring

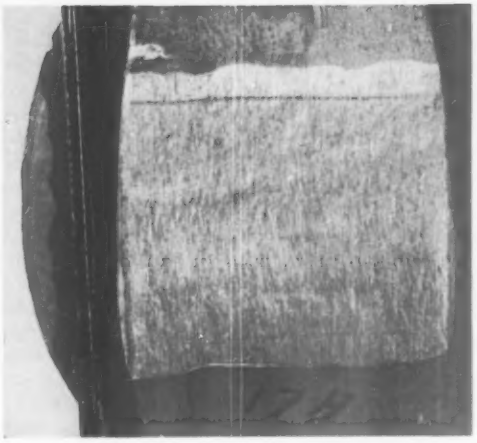

Fig. 4 Bend test of simulated two-layer clad weld made with special 27 Cr–13 Ni electrodes in ¾-in. mild-steel plate in the horizontal position

Fissuring is prevented by the presence of ferrite in the microstructure

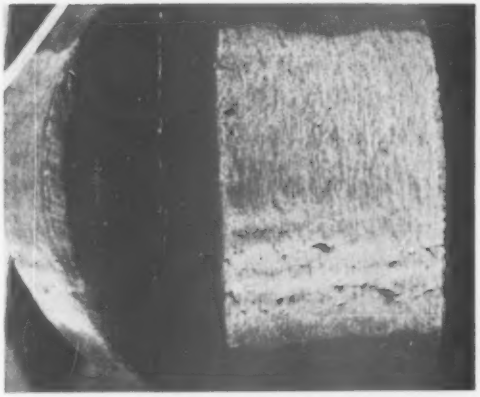

Fig. 5 Bend test of simulated two-layer clad weld made with 0.09 C, 25–20 electrodes in the first layer and 19–9 electrodes in the second layer in ¾-in. mild steel plate in the horizontal position

Both layers are undoubtedly fully austenitic and are susceptible to fissuring. Test was conducted to illustrate that ¾-in. plate offers sufficient restraint to cause weld metal to fissure

elongation was 32% in the as-welded condition. If too much ferrite is introduced the strength of the weld increases resulting in a separation of the fusion line. In Fig. 4 both layers were deposited using a special 27Cr–13 Ni electrode. The weld was made in ¾-in. mild steel plate in the horizontal position. The elongation was 23%, as-welded. Better ductility would have been realized if the second layer had been deposited with a 19–9 electrode, thus reducing the ferrite content of the second layer.

We realize that our procedure is open to criticism because we did not weld in 410 clad plate and the plates were only ¾ in. thick. In the "strip-back" procedure wherein a rather wide but shallow groove must be filled in the horizontal position, the clad metal enters the weld at only the "bottom" and "top" beads. All other beads are deposited in a combination of mild steel and prior weld metal. Hence we feel that the simulated groove using mild steel is a valid extrapolation for testing weld metal only. To test for fusion-line and heat-affected zone defects, clad plate must be used.

Figure 5 is presented to illustrate that ¾-in. plate is capable of producing a fissure-type failure. This weld was made in the horizontal position using 0.09 C, 25–20 for the first layer and 19–9 for the second. Both layers were undoubtedly fully austenitic and were subject to fissuring. This specimen exhibits 40% elongation but the fissures were pronounced when the elongation was only 14%. The specimen is in the as-welded condition.

The foregoing results were selected from a series of tests representing eleven combinations of electrodes. Some combinations were used to satisfy curiosity, but most were selected on the basis of hypotheses and the results of preceding tests.

We feel that if the 0.15 to 0.20 carbon 25–20 electrode can be used this is probably the simplest method of approaching a solution to the problem. Solving the problem by introducing ferrite involves a careful selection of electrodes to obtain an optimum amount of ferrite in the beads.

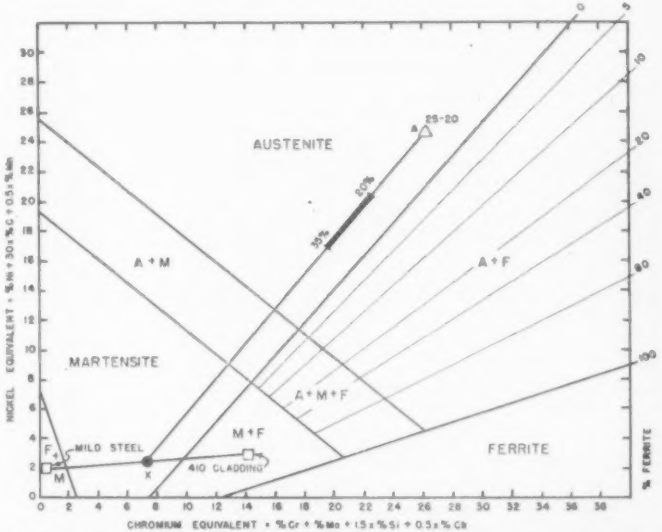

Fig. 6 Tentative constitution diagram for weld metal illustrating the welding of 410 clad steel with 25–20 electrodes

The diagram shown in Fig. 6 gives a visual approach[5, 6] to the problem. In Type 410 clad steel both 410 and mild steel are melted simultaneously when depositing the first bead. This is represented by point *x* on the diagram. If a normal 25–20 electrode is used the resulting deposit will be fully austenitic (dilution ranging between 20 and 35% on line *ax*). This deposit or any fully austenitic deposit will be subject to fissuring if the restraint during welding is great enough. However, if a high-carbon (0.15 to 0.20) 25–20 electrode is used, the character of the austenite is changed; the deposit is more resistant to fissuring.

Figure 7 is included to illustrate what occurs when an electrode capable of producing a partially ferritic deposit is used. A 29–9 electrode is selected for the first layer and again the first bead is directed at point *x*. With 20 to 35% dilution the first bead is found to contain about 25% ferrite. The second bead is welded in a combination of Bead 1 and mild steel. If equal amounts of Bead 1 and mild steel are melted the dilution direction line will be drawn from the 29–9 electrode (point *R*) to point *y*. Bead 2 is found to contain about 20% ferrite. The remaining beads of Layer 1 can be followed in a similar manner. All beads will contain an adequate amount of ferrite for the prevention of fissuring; in fact, with this large amount of ferrite the weld may be too strong causing the fusion line to separate during bending before the required elongation is realized. We feel that a 27 Cr–13 Ni electrode (point *S*) which would deposit a bead containing only 10% ferrite is a better electrode to use for the first layer. Even 5% ferrite is believed to be adequate to prevent fissuring. The 25–12 Cb electrode (estimated to fall at point *T*) used by Mr. Arnold for the first layer would theoretically deposit about 5% ferrite. I believe that the presence of ferrite rather than the introduction of columbium explains why Mr. Arnold obtained excellent results with a 25–12 Cb electrode.

A 19–9 electrode will be satisfactory for the second layer regardless of which of the ferrite-bearing electrodes is used for the first layer. One can observe that the dilution direction line from a 19–9 electrode (point *U*) extends toward the locations marked *First Bead* and *Second Bead* of the first layer, if 29–9 is used for the first layer, and hence the second layer using the 19–9 electrode will contain about 10% ferrite.

When using a ferrite-bearing electrode for welding it may be wise to leave the weldment in the as-welded condition because the ferrite is susceptible to transformation to brittle sigma. The transformation of ferrite to sigma at 1100 or 1150° F. is certainly not as rapid as it is at 1300 or 1500°F., but it may cause trouble depending upon the percentage of ferrite and the length of time the weldment is held at the stress-relieving temperature.

If the ferrite method is used to solve the problem, we believe good results will be obtained using an electrode containing between 24 and 27% chromium and about 13% nickel for Layer 1 and a 19–9 electrode, containing between 4 and 10% ferrite for Layer 2. This is essentially the recommendation of Mr. Arnold except that he used a columbium-bearing electrode for the first layer.

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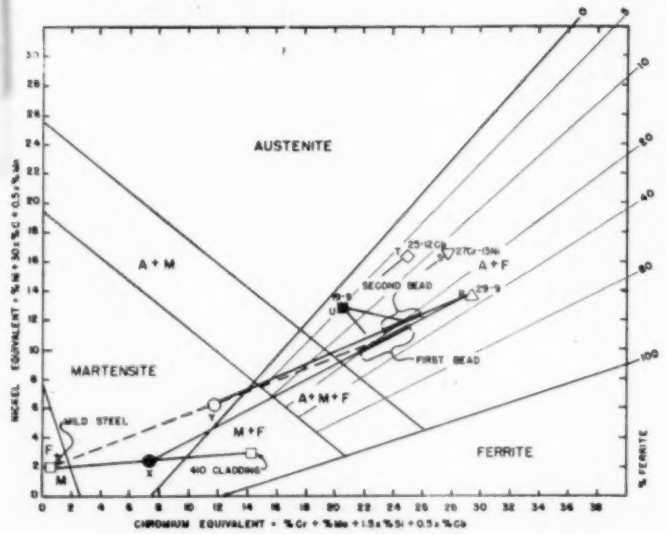

Fig. 7 Tentative constitution diagram for weld metal illustrating the welding of 410 clad steel with several different electrodes

Automatic Electric Hard Facing

A practical cross section of the methods and fields open to the automatic submerged melt hard-facing process

by Turner G. Brashear, Jr.

AUTOMATIC submerged melt welding although not new, continues to widen the scope of welding. The process offers advantages such as increased production speeds, together with lowered costs and higher quality products. Recent developments have broadened the automatic applications by expanding to include hard facing.

Today nearly all phases of industry recognize the important part that hard facing has to play. Practically all of the reasons surrounding hard facing pertain to economy. Examples of economy include longer life, less shutdown time and continued uniformity of surface shapes subjected to abrasion and impact.

The surface wear phenomena caused by the cutting action of abrasives has been the problem that our efforts have focused on. This wear problem can be combated by depositing a hard surfacing overlay, on the wearing parts, of $^1/_{32}$ to 2 in. and over depending upon the article being welded.

This method of armor plating parts subjected to severe service presents a versatile tool to the welding engineer.

SELECTING ROD

Selection of the welding rods and deposition techniques are gradually being computed on the basis of theoretical and past performances. The bare rod applications via the gas torch and the flux-coated and bare-fusion methods are now standard practices.

There exists a tremendous wealth of alloy combinations that can be utilized in the form of a welding rod. A number of combinations have been selected for commercial exploitation under various trade names. Until a great deal more validated wear tests are forthcoming the immediate development of standards and specifications is unlikely. If hardness alone is specified as a guide many applications will prove disappointing.

One classification of hard-surfacing alloys groups them on the basis of composition such as low-alloy cast irons, alloy steels, alloys containing 50 to 80% iron, nonferrous alloys, very hard refractory carbides and composite rods resulting in a mixture of tungsten carbide in a matrix which in itself may be a hard-surfacing alloy.

The constitution and structure of metals has been generally established as being the fundamental factors that determine the wear-resistant properties. Composition as determined by chemical analysis is important and may be decisive in the production of a desired structure with its attendant properties; but other factors such as heat treatment may be more influential. It is possible to produce several structures by different treatments of the same alloy. Therefore, it is desirable to classify hard-surfacing deposits in terms of structure when possible.

ECONOMICAL ASPECTS

It was only natural that the economical aspects of hard facing could be benefited by the utilization of automatic welding equipment. The advantages of automatic hard facing parallel those found in conventional automatic welding. The important advantages include:

1. Continuous welding.
2. Superior weldments (surface appearance, density, smoothness).
3. Increased duty factor accompanied by economy in no stub-end loss.
4. High welding speed (due to arc control and high-current densities).
5. Being able to use semiskilled operators.

In manual hard facing the question of operator techniques is an important factor contributing to weldment results. This factor is overcome by replacing the manual dexterity and questionable know-how of the operator with the volt, ampere and speed combinations prescribed by the automatic process.

AUTOMATIC WELDING

The problems of converting the alloyed rod from manual to coiled form has been successfully attacked by several electrode manufacturers. They have taken into account the metallurgical and mechanical diffi-

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Fig. 1 — 4½ ft. Simons Cone (Mantle)

culties encountered when applying these alloys at extremely high-current densities through the submerged-melt media. They have modified their electrode compositions to compensate for the resulting high per cent of dilution. Some of the coiled rods now being offered utilize a fabricated rod where the alloys are contained in a powder form in the hollow core of the rod. A great deal of consistent success has been met with these rods as the manufacturers now offer a complete line of automatic rod which covers nearly the entire field of hard facing as we know it today. One of the problems that were overcome in conjunction with coiled fabricated rods included a method of engaging the rod in order to feed it through contact jaws without crushing it. Special jaws and driving rolls are now available which overcome all rod feed difficulties. Any conventional head can be adapted to the rod.

Another manufacturer offers a composite rod which includes a special fluted-carbon or low-alloyed rod about which an alloyed coating is extruded. Electrical contact is made with the rod by means of helically wrapped wires which contact the base rod and protrude through the sanded coating. This rod was primarily designed for open-arc applications but does an excellent job when used in conjunction with submerged melt hard facing. Excellent arc control is maintained throughout the practical current ranges. The important factor about this rod is economy, for although the alloy percentages that can be obtained are limited, it nevertheless fills a gap at a very competitive price. Crushing of the coating is overcome by means of an adapter including neapreme drive rollers. Electrical contact is made through special tungsten inserted jaws designed to surround the rod and take advantage of all surface areas open for contact.

Fig. 2 — 4½ ft. Simons Cone (Bowl Liner)

A third type of automatic hard facing is currently being offered that includes a carbon-steel or low-alloyed electrode to be used with an alloy-enriched submerged melt flux. A conventional mild-steel rod is usually used and the hard-facing alloys are picked up from the flux during welding. This process has great potentialities, particularly as a semiautomatic tool. Where a relatively hard but flexible rod of small diameter is employed to insure operator efficiency. The need for a rod to resist deformation during flexing precludes the use of fabricated or flux-coated rods (however, both types have been used with the semiautomatic with limited success). To date the percentages of alloy pickup cannot be closely controlled or predicted as they are constantly varied with speed, voltage, amperage, preheat, and heat builds up changes. Perhaps tables can be formulated and will be forthcoming whereby given setups will result in given weldment compositions.

Fig. 3 — 3 ft. Simons Cone (Hadfield manganese)

A fourth method involving combinations of these foregoing processes, plus controlled inert arc atmospheres, is also being explored; however, it is too early to predict results.

The question of what rod to use is best answered by

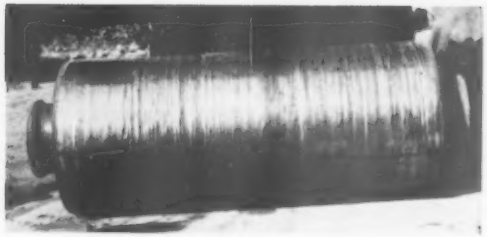

Fig. 4 1500 lb. Ladder Roller

assembling the facts and following the recommendations prescribed for former hand-welding performances. A comparable automatic rod can then be selected from a reputable manufacturer who offers a modified hand rod in coil form.

The choice of automatic welding equipment is more or less dictated by the size and condition of the shop or department directly concerned with the operation. There are many commercial heads available and all perform fairly well, in view of the fact that most hard-facing applications fall in optimum automatic welding condition ranges; that is, the arc control and burn-off rates are located in easily controlled bands. The first considerations are maintenance and simplicity. Flexibility and portability should also be considered. The major difficulties encountered so far are the feed mechanisms which have been designed to grip solid wire. The relatively soft tubular rods and coated rods are subject to deformation and cracking under pressure. For this reason the feed rollers must be grooved and knurled or faced with neapreme or rubber so that a positive feed without excessive pressure results under all conditions. The only function of the automatic head is to maintain a constant predetermined arc length. For complex and irregular shaped surfaces a semiautomatic or a head mounted on a panagraph can be utilized.

Of the many types and grades of submerged-melt fluxes open to the process the black melt No. 90-12 x 150 seems to be the best for low alloy applications. This manganese silicate flux appears to be one of the fluxes that evidences any effects of polarity. Rod burn-off rates vary with 90 melt when polarities are reversed. On straight polarity more rod is consumed per setup than when reverse polarity is used. This manganese flux further evidences better arc control, less penetration, fewer pinholes and rapid solidification, all of which are important when hard facing. Other fluxes are available when extreme current densities, corrosion-resistant, or high alloy problems are present.

The choice of alternating or direct current has not been fully explored for hard facing but the trend is graduating toward a. c. It was previously accepted that d. c. offered a more flexible source of arc control but repeated tests indicate that with all of the commercial grades of alloyed coiled rods now available for hard surfacing, a. c. definitely minimizes surface checking and materially benefits weldment densities. The reasons behind superior alloyed weldment qualities when using a. c. is not fully understood. Puddle agitation and the minimizing of crater formation on rod and work may influence the weld. The economies of a. c. are becoming more accepted by the industry due to simplicity, economy of maintenance and the saving in power from no load losses during down time.

When welding continuously on production hard surfacing, conventional controls must be exercised. Natural human deficiencies can be counteracted by having adequate welding positioners, instruments, controls and welding tables available to the operator. The choice of positioning equipment, fixtures and jigs should be simple but well thought out.

The various methods of retrieving unused flux, regrinding fluxes, utilizing positioners and automatic move-overs are generally familiar to those associated with the trade. The welding head can be made to move transversely at the completion of each bead when surfacing a cylindrical object by means of a screw, travel carriage motor or movement of workpiece. Time delays are utilized to insure uniform move-overs when the surface to be welded is perfectly flat and

Fig. 5 Typical Gold Dredger

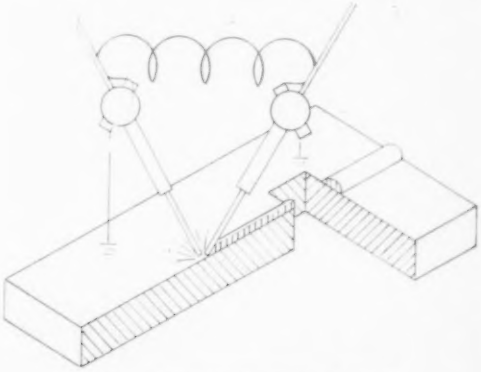

Fig. 6 Series arcs in common puddle

Fig. 7 Caterpillar Idler

needs no varying more over changes to compensate for uneven degrees of wear. This latter problem is overcome by calculating the degrees of wear and depositing the beads close together or wide apart according to the demands of the worn object.

The major fields of applications open to automatic hard facing are maintenance and manufacturing applications.

Automatic hard facing offers the manufacturer a method of economically producing uniform, high-quality, long-wearing parts.

At present there exists a large field for the privately owned job shop. These shops have already been organized because of the immediate need for reclaiming expensive parts. Some of the applications now being successfully hard surfaced every day are presented.

Figure 1 illustrates a hard-faced, 4 1/4-in. standard Hadfield manganese Simons cone. This mantle exemplifies the type of equipment subjected to severe service in the field. Here the hard-facing rod must be carefully selected as extreme impact and abrasion are simultaneously encountered in this rock crusher. The rock-products field offers a good field for automatic hard facing in that the crusher rolls, cones and bowl liners are of such a size and shape that they lend themselves to the process. This hard-faced cone will more than crush an amount of rock equivalent to the full life of a new cone before the 2/16- to 1/4-in. hard-facing layer is worn away. It is now standard practice to hard face new parts, place them in service until the overlay is removed and then reface them before they become too thin in cross section. The danger of warpage so prevalent in manganese is minimized by the uniform and rapid heat input. The temperature of the mantle becomes almost uniform after a few circumferential beads are welded. The danger of weldment boundaries and casting embrittlement is also critical when welding manganese. Embrittlement has been controlled by packing the cone with dry ice; a tremendous heat gradient was established between the back side of the mantle and the welding zone. One's hand could be held immediately adjacent to the weld without fear of becoming burned; subsequent tests using water vapor sprays and more dry ice materially increased the life of the hard-faced crusher. The temperature of the cone during welding must not exceed 500° F. for the best results.

Figure 2 shows a 4 1/4-ft. corrugated bowl liner. Note the uniform bead spacing brought about by circumferential speed control and an automatic move-over. This liner will require approximately 16 hr. welding time during which 185 lb. of hard-surfacing rod will be deposited.

Figure 3 pictures several of the cones as illustrated in Figs. 1 and 2. The smaller of these cones is a rebuilt one. Welding took place over the work-hardened area which unlike fully heat-treated manganese registered a relatively high degree of magnetism. Penetration carried down through the 1/8-in. work-hardened surface. Excessive checking was prohibited by using a. c. It is questionable as to how many times these bowls and mantles can be rebuilt and surfaced. It will probably depend upon the heat vs. time cycles employed in welding as well as the degree of work hardening in the field. These castings, which are zinceked in place, and must be held to close tolerances were found to have warped less than 1/16 in. in any direction during welding.

Figure 4 is a 1500-lb. cast-steel ladder roller employed by the gold dredging industry. Approximately 120 lb. of build up rod was applied prior to hard facing. There are from 30 to 50 of these rollers per dredge and their

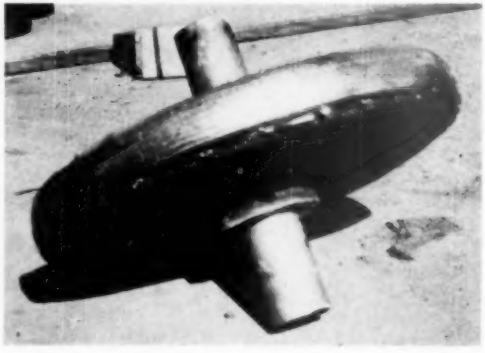

Fig. 8 Power Shovel Roller

normal life span ranges from 2 to 6 mo. depending upon the type of ground being dredged and the positions of the roller in the line.

Figure 5 depicts a typical dredger. Note the bucket line. These 18-cu. ft. manganese buckets travel over the ladder rollers at a rate of 38 buckets per minute. Present data indicates that the hard-surfaced rollers will last up to 5 times as long as original rollers and will materially cut down bucket wear.

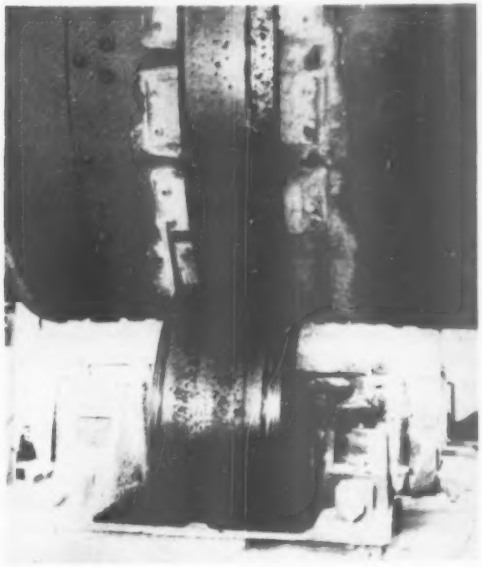

Fig. 9 Rotary Kiln Tire and Trunnion

The roller represented in Fig. 16 is common to all areas as it is a truck roller used on caterpillar equipment. Each large caterpillar tractor has from 10 to 12 of these rollers. Their average life, depending on upkeep and work conditions, is in the neighborhood of 2000 hr. on flat ground. The life of these rollers can be increased from 3 to 4 times at a fraction of their original cost. Naturally the low alloy metal used for reclaiming rollers is the reason for the life extension. It has been proved that hard-faced rollers definitely cause less wear on track rails. The welding time on these rollers varies from 30 min. to an hour depending upon how many passes are needed to return it to the original dimensions. Several methods have been tried to increase welding time such as circulating water within the bore. This allows higher deposition rates because heat build up is lessened.

The caterpillar idler depicted in Fig. 7 was built up in the same manner as the rollers. The time involved to deposit the 35 lb. of build-up rod and 15 lb. of low-alloyed hard-facing rod was $4^1/_2$ hr. The flanges can be built up when worn by laying beads continuously one over the other.

Many power shovel rollers and idlers fall in the

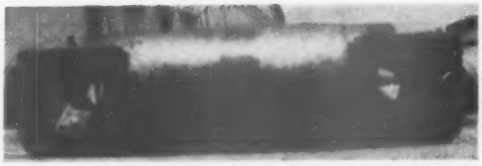

Fig. 10— 4 in. Shovel Idler Shaft

category illustrated by Fig. 8. Here tremendous weights must be considered along with severe impact and abrasion. In all of these cases the surfaces of these parts are sufficiently smooth in the as-welded condition to be entirely suitable.

Illustrated in Fig. 9 is a rotary kiln tire 13 ft. in diameter. This tire had suffered a great deal from galling. One half of its area had been worn away due to a peculiar abrasive found in the oil between the trunnion and the tire. The rim was preheated to 400° F. and 600 lb. of rod was applied. Prior to rebuilding the tire the trunnions were ground $^3/_{32}$ in. undersize at the point opposite the tire wear. The tire was then built up $^2/_{32}$ in. oversize after which it was ground flush. This was followed by grinding the trunnion flush. The outstanding fact regarding this application was that no lost time was encountered as the welding, etc., was carried out during kiln operation. An estimated $30,000 was saved on this reclaiming job.

A 4-in. power shovel idler shaft is shown in Fig. 10. This scored, worn shaft was hard faced, normalized and ground for less than 50% the price of new. Diameters down to $2^1/_2$ in. have been successfully hard faced by means of applying the beads in a spiral. The spiral enables the point of fusion to remain on the top surface long enough to allow weldment solidification. Less distortion is encountered with a spiral build up. This spiral method may be of interest where considerable small diameter rounds in long lengths are subjected to wear.

Figure 11 is a transition found in a continuous pipe mill. An extremely high metal-to-metal abrasion

Fig. 11 Pipe Mill Forming Transition

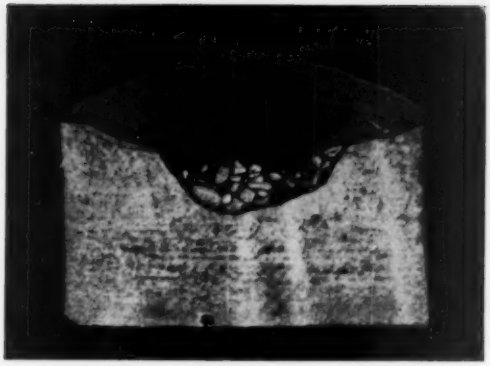

Fig. 12A Conventional penetration

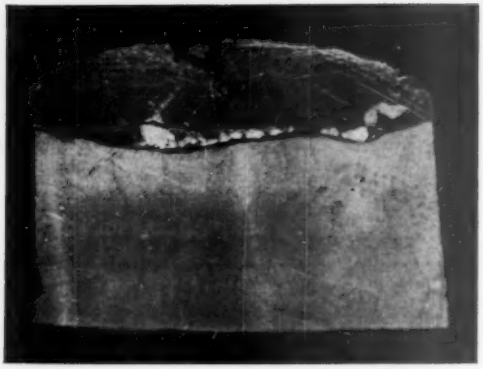

Fig. 12B Penetration using same energy input per lineal inch as 12A

factor is present in service. Approximately 12 lb. of rod was applied in 1 hr. and 20 min. welding time. Grinding time was kept to a minimum due to the smooth even contour of the automatic bead.

A few words should be devoted to the subject of buttering or bonding a hard-to-weld metal with stainless steel. Many persons in the industry use stainless as a cure-all and it is natural that it has found its way into automatic hard facing. Results of adding a layer of stainless to an article such as a Simons Cone, prior to hard facing, has proved unsatisfactory. The stainless steel deforms under impact before work-hardening causing the relatively soft mass immediately under the hard-surfaced skin to slip resulting in weldment cracking. The low-carbon content of stainless tends to dilute the hard-facing alloy and further lessens the efficiency of the deposit. Generally speaking stainless steel has not proved satisfactory as a bond for hard surfacing or as a wearing surface.

Figures 12 to 15 introduce a method of overcoming the dilution problem with automatic welding and at the same time permitting 50 to 100% plus greater deposition rates per given energy input than with conventional setups.

Both beads in Fig. 12 were deposited with the same energy inputs per lineal inch. The outstanding fact to notice is the difference in penetration.

Surfacing by any process requires the complete fusion of the added material to the base metal, and the quantity of the material added is reflected by the thickness of the deposit. Union melt welding, as generally practiced, fuses a larger proportion of the base metal which uniformly mixes with the welding rod. The quantity of base metal fused is often twice as much as the quantity of rod fused.

When the purpose is to deposit weld metal, not to fuse the base metal, it has been desirable to avoid the usual rod dilution, particularly when dissimiliar rods are employed.

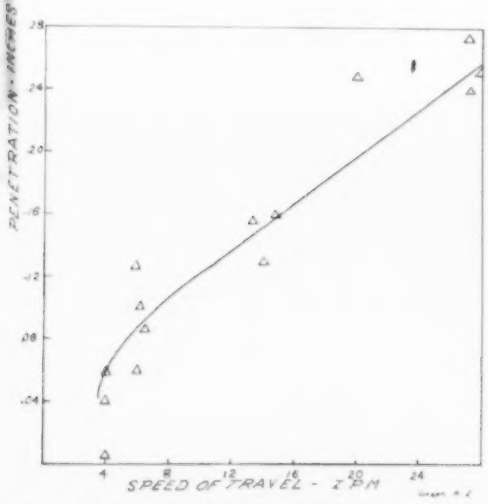

Fig. 13 Effect of speed changes on penetration using constant energy inputs per lineal inch

Fig. 14 Two electrode arc deposits

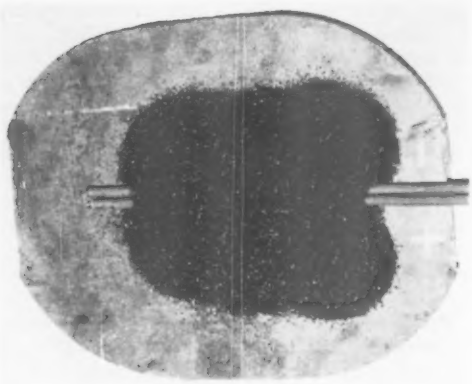

Fig. 15 Fundamentals of series welding

In addition to chemical losses due to rod dilution there are definite chemical losses brought about by the welding action. Approximately 20 to 30% of the available carbon is lost, this loss being little effected by varying degrees of preheat. Carbon loss is definitely effected by the speed of welding and is greater at lower speeds.

When using manganese silicate flux a proportionate gain in manganese pickup is evidenced.

Chromium losses* approximate 10 to 20% of the total available, this percentage of loss decreases as the total amount of chromium in the deposit increases. The loss of nickel, molybdenum and vanadium is practically nil.

The silicon content tends to increase with the added number of passes toward an equilibrium point between 0.40 and 0.60% with base and rod metal of a nominal 0.15 to 0.25% silicon content.

If normal welding process techniques are used with multipass welding the deposited weld metal reaches equilibrium after about three layers.

It is desirable to be able to predict chemical compositions for single-pass alloy deposits. This can be done by mathematically computing the percentages of dilution and the alloy percentages in rod and base metal.

One standard method of controlling penetration and dilution is to follow the automatic set-up techniques dictated by Fig. 13. Here it is obvious that as the speed of welding increases the percentage of rod fused as compared to base metal fused decreases and the penetration becomes surprisingly greater. A low travel speed must be employed in order to decrease penetration.

Another factor contributing to penetration is voltage. Weld tests indicate that an increase in voltage for a given energy input will decrease the rate of rod burn off and penetration.

Combinations of low speed, low current, high voltage and straight polarity will result in a minimum of penetration; but accompanying this desirable penetration are the undesirable factors of low rod burn-off rates, increases in the depth of the heat-affected zone, practical mechanical difficulties in controlling metal run-offs on small diameter rounds, and increased losses of alloying elements (particularly the dissolving of the tungsten carbides when the latter are employed). Finding a compromise in speed, volt and amperage setups is difficult.

Present experiments indicate that with a two electrode arc (connected in series) penetration is confined to 5 to 20% of the fused area regardless of speed, voltage or current changes. These facts allow high welding speeds, high deposit rates, minimum heat-affected zones, all of which contribute to hard-facing efficiency.

Ease in arc-voltage control is evidenced with this method. Perhaps this can be explained by considering the arc zone as a separate voltage control; that is, as either electrode tends to burn off faster a resulting increase in its voltage results in a corresponding current drop, all of which aids the natural function of the automatic head employed in the voltage control.

Bead *A* in Fig. 12 was made with conventional weld-

* Information supplied by The Linde Air Products Co.

Fig. 16 Caterpillar truck rollers

ing techniques. Note the high percentage of penetration. Bead *B*, Fig. 12, was deposited with the low-speed, low-current, high-voltage technique. Although penetration is lessened to approximately 25% of the fused zone all of the undesirable factors have occurred.

Figure 14 exemplifies the type of bead, with its attendant fusion zone, deposited by the two-electrode arc. Here approximately 10% dilution is encountered. This bead was deposited at the same energy per lineal inch input as were the beads in Fig. 12.

Physical tests and field tests indicate that a small degree of penetration is sufficient to withstand spalling tendencies of severely strained weldments while delivering the maximum percentage of abrasion resistance. At the termination of the weld no visible crater is evident.

Figure 15 pictures the fundamentals necessary to lay down a bead similar to the bead in Fig. 14. The two electrodes are insulated from each other and then connected in series. Spacing of the electrodes from each other and/or the workpiece affects the depth and width of the bead deposit. No skill whatsoever is required to operate this simple setup. If the rods are separated over an electrode width or over 1/4 in. the weldment reverts back to the deep penetration as illustrated in Bead B, Fig. 12.

The simple drawing in Fig. 6 illustrates a method of duplicating the bead in Fig. 14 with continuous welding by utilizing coiled rod and two automatic heads. It is also possible to drive both rods from one head. Here the electrodes are again in series. A great latitude is allowable for electrode-to-work distance deviations before any visible weldment changes are apparent.

With the two electrodes connected in series nearly all of the available energy is utilized in depositing rod. It is possible to deposit better than 150 lb. per hour with this method. The voltage across the two electrodes will be twice the voltage drop between electrode and work; this high voltage contributes to a beneficial high-power factor.

The current flow between either individual electrode and workpiece is sufficient to operate any of the conventional automatic heads now being merchandised.

This paper has not attempted to give any detailed technical information on any particular phase of automatic hard facing. It is my hope that those hearing this report now have a better understanding of the present and potential scope of the process.

ACKNOWLEDGMENT

The author wishes to acknowledge the assistance of Mr. George Staley of Stoody Co. for supplying information and test data.

CURRENT WELDING LITERATURE

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(*Continued on page 402*)

Design Features of a Welding Generator

Electrical characteristics of generators needed for arc stability. Electrical circuits, magnetic circuits and controls indicated

by Dr. Joseph M. Tyrner and O. Kobel

WHEN a designer is confronted with the problem of developing a new d.-c. welding generator, he has to satisfy a wide variety of requirements. First of all, he has to choose or to invent a circuit which provides a drooping volt ampere characteristic and an output control with as wide a range as possible. After the circuit has been selected, the correct combination of reactance, resistance and generator response has to be incorporated. This combination controls the transient characteristics and with it arc behavior. When welding with electrodes which transfer metal in globular form incorrect transients might lead to "popouts." The combination of reactance resistance and generator response also controls the ease of starting the arc as it determines the size and shape of the initial current surge. Too small a surge makes starting difficult and a surge which is too large causes burning through, when working with thin sections. Not only the size, but also the shape of the surge is important. It has been shown that a slow decline is desirable because it prevents freezing of the electrode to the workpiece in starting.

Another electrical feature of the generator, which depends on the circuit, is the change of output from cold to hot conditions. This change should be as small as possible, because it is very irritating for the operator if he has to readjust the control too often.

And last but not least, the electrical circuit should be simple, devoid of fancy coils, windings and pole pieces for ease of manufacturing and maintenance.

In mechanical respect the severe service conditions to which a generator is exposed cannot be overemphasized. Ruggedness of every part is essential. Here again simplicity of the circuit helps to make for mechanical simplicity and accessibility of every part.

In our design of a welding generator we approached the problem of selecting a circuit from the economical side. It is obvious that the least expensive choice of generator should be a standard and completely conventional generator in which the whole circumference of the armature contributes to the generation of the open-circuit voltage at as high an air gap induction as possible.

Such generator, especially when built as a 2-pole machine running at 3600 rpm., inherently does not have sufficient reactance for good welding performance. This reactance could be provided inside the generator frame only with some kind of additional features like special coils or iron paths. But these features would be a departure from the simple form of a generator and, as such, would increase its size and cost. We concluded, therefore, that the most economical solution of this problem would be to use an outside reactor. This reactor could be built for the desired reactance without interfering with generator features. So far so good. We had arrived to the use of two standard units, but they had to satisfy volt-ampere characteristics and control requirements of a welding generator. The first problem found its solution in an interlinking of the iron paths of the generator and reactor which was done without losing the simplicity of the two units. The second problem was solved by equipping the reactor with a variable air gap.

The cross section of the generator which is shown in Fig. 1 illustrates that the new machine actually is a combination of a conventional generator and a reactor with a variable air gap. A reactor designed primarily to satisfy requirement of arc performance and a generator designed to carry a certain load are made to work together as a welder.

The generator consists of the armature, *1*, which rotates inside the frame, *2*. Of the two pole pieces *3* carries shunt excitation while *3'* is separately excited. On top of the frame is the reactor consisting of the core, *5* and *5'*, and the moving control plug, *6*, which is surrounded by the two coils, *7*, which are excited by the welding current. The air gap at *8* is adjusted by raising and lowering the control plug, *6*, by the handwheel, *9*.

The welder operates in the following way. The magnetic flux of the generator follows the path *ABCDE*. It is interlinked with the magnetic path *ABFG* of the reactor between *A* and *B*. The magnetic potential drop between *A* and *B* is a function of the total flux in that part which is the sum of generator and vector fluxes. An increase of the welding current increases

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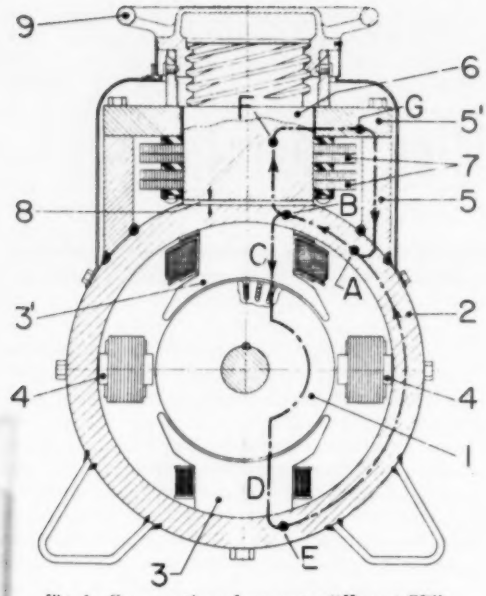

Fig. 1 Cross section of generator "Hornet CX"

the reactor flux and with it the magnetic potential drop from A to B. This potential drop is also imposed on the magnetic circuit of the generator as it opposes the excitation of the armature flux. Consequently, when the welding current is increased, less of the generator excitation is left to drive flux through the armature for the generator of voltage. Finally, at short circuit the drop between A and B becomes so high that it essentially equals all the available excitation of the generator. In this way, by interlinking flux paths, the reactor provides the drooping volt-ampere characteristic desired for a welding generator.

An electric analogy might explain this magnetic circuit further. The two magnetic paths of the generator-reactor system are replaced by the two closed circuits, R and G, where R represents the reactor and G the generator branch. Reluctances are replaced by resistances, fluxes by currents and magnetic excitations by voltages. The two branch circuits show the resistor, r_{AB}, between A and B as an electric equivalent of the common flux path A and B. In branch R with the voltage, v_R, flows the current, i_g, and in branch G with the voltage, v_g, the current, i_g. The sum of the currents, $i_R + i_g$, flows in the resistor R_{AB} and causes a voltage drop $(i_R + i_g)r_{AB}$. This drop increases if an increase of the voltage, v_R, causes an increase of the current, i_R. But this voltage drop opposes the voltage, v_g, which drives the current, i_g, through the branch, G. If the drop, AB, equals v_g no current flows in branch G, which is the electric analogy for the lack of magnetic flux in the generator for short-circuit condition.

MAGNETIC	ELECTRIC
EXCITATION	VOLTAGE
FLUX	CURRENT
RELUCTANCE	RESISTANCE

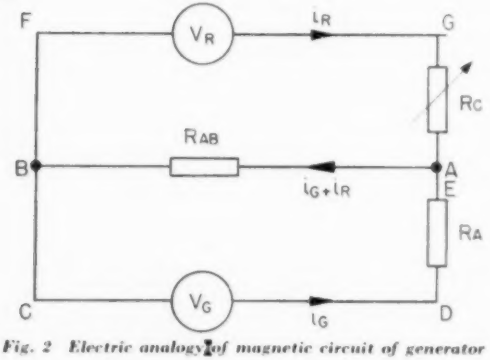

Fig. 2 Electric analogy of magnetic circuit of generator

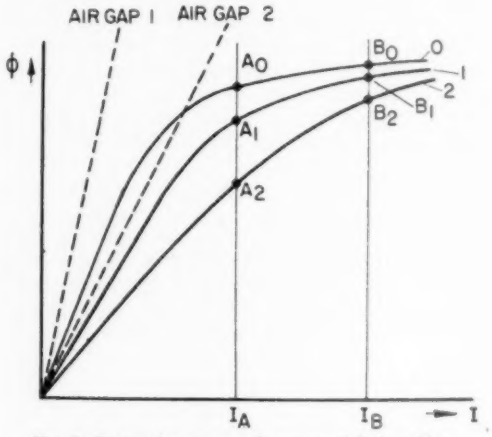

Fig. 3 Saturation curves of reactor with d.-c. bias

It can also be seen in this equivalent circuit that the voltage drop AB with all its consequences may be controlled by the variable resistance, r_c, which is the equivalent of the variable air gap. If this resistance is high, more voltage, v_R, is necessary to obtain the current i_R, which prevents the flow of current in branch G. More voltage, v_R, is equivalent to more welding current in the welder. Therefore, a large air gap in the reactor causes a large output of the generator.

This method of controlling the output has a very decisive advantage. Reactances in d.-c. generators work with superimposed d.-c. excitation, and saturation of the iron core has to be avoided by interrupting the continuity of the iron path by an air gap. This is illustrated in the diagram, Fig. 3, which shows the magnetic flux as a function of the exciting current I. Curve (o) is the saturation curve for a continuous iron path. By introducing the air gap, (1), we obtain Curve (1) while the larger air gap, (2), leads to Curve (2). Considering the condition for the d.-c. bias, I_1 we find that the uninterrupted path becomes saturated.

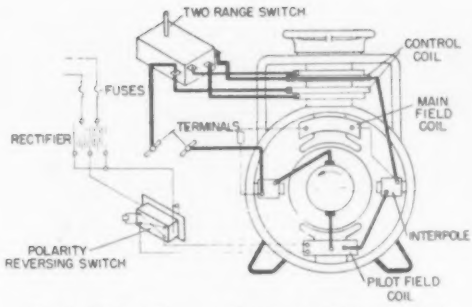

Fig. 4 Wiring diagram of generator "Hornet CX"

The iron path with the air gap, (*1*), however, is not saturated. Neither is the iron path with the larger air gap, (*2*); however, the resulting flux is smaller than for air gap (*1*), and therefore air gap (*2*) gives less reactance and is less economical. If the d.-c. bias is increased to I_2, even the core with the smaller air gap is saturated and the large gap becomes necessary. Evidently for every value of the d.-c. bias or, in other words, for every welding load, an air gap exists which offers best conditions. In a reactor with fixed gap the only possible adjustment to the condition of the varying load is a change of turns on the reactor. This can be done by using a different number of turns on the reactor for the various range steps of the generator. A compromise becomes necessary as the gap offers optimum condition only for one load which is too large at the low end but too small at the high end of the range step. In both cases the effective reactance is reduced. The only way to improve on this is to build the generator with many range steps. If the generator has no separate reactor but depends solely on the inherent reactance of its circuit, conditions are identical but still harder to control, which is an additional disadvantage. On the other hand it is quite obvious that the control reactor of the new machine never reaches saturation.

Another feature which might be mentioned here is a

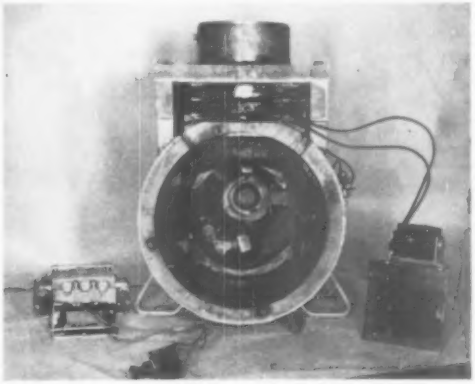

Fig. 5 Generator with bearing brackets removed

Fig. 6 Generator disassembled

2-range switch which connects the two coils on the reactor in series or in parallel. It has been stated before that one of the requirements for best arc performance is a certain amount of resistance. The adjustment of the resistance is achieved by dividing the full range of the machine into two steps with the higher resistance provided by the series connection of the reactor or control coils.

Polarity of the generator is controlled by separate pilot excitation in accordance with our practice. This makes the polarity of the unit absolutely stable and avoids accidental polarity reversal. A desired change of polarity may be achieved by reversing the pilot excitations.

A pictorial wiring diagram, Fig. 4, illustrates the connection of the generator. In the circuit of the welding current are only armature interpoles and the control coils on the reactor. The series coil which is indicated at the bottom pole consists of one turn of the connecting cable between armature and interpole. Aside from

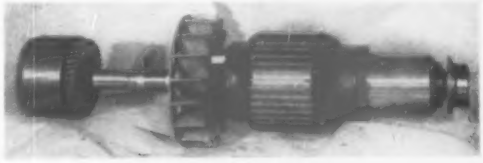

Fig. 7 Armature and rotor

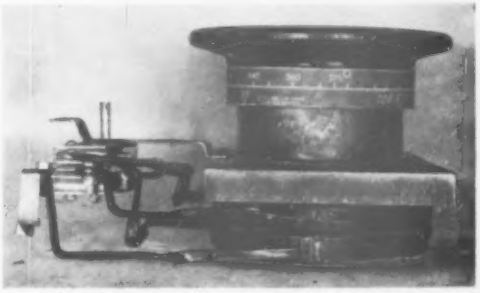

Fig. 8 Control assembly

Fig. 9 Control plug with control handwheel

Fig. 10 Welding generator rated 300 Amps

this one turn the two main poles carry only separately, respectively, shunt-excited coils.

It has been stated at the beginning that the generator should not change its output from cold to hot. In this generator the excitation of the generator is achieved by two well-cooled coils on the pole pieces, *3* and *3'*. Actually the load and heating of the shunt coil decreases when the generator delivers welding current because the voltage impressed on this coil is the arc voltage instead of the higher open-circuit voltage. The pole pieces carry essentially no series excitation which in other generator systems heats the exciting coils and raises their resistance. The consequence of this construction is an output practically unaffected by the load conditions of the generator.

Pictures of the generator illustrate its simplicity further. Figure 5 shows the frame with the reactor on top. The components of the generator are illustrated in Fig. 6 which shows the two pole pieces, their exciting coils and the two interpoles. As can be expected, the armature of the machine is completely conventional as shown in Fig. 7.

The control of the generator is a self-contained unit which is illustrated in Fig. 8. Control coils and their series parallel switch are attached to the top plate of the reactor, which also carries the mechanism for raising and lowering of the center plug. This plug with its heavy screw thread and the control wheel is illustrated in the next picture, Fig. 9. Incidentally, the control plug is moved through its complete stroke by one turn of the control wheel. The concluding picture, Fig. 10, finally gives the completely assembled unit with its pleasing lines.

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Welded Fabrication in Heavy Plate

by J. B. McCormick

THE advantages of using arc welding in fabricating accrue in proportion to the amount of imagination and ingenuity exercised in the application of the process.

Some of the many possibilities of extending the application of arc welding are excellently illustrated in the operations of the Los Angeles plant of the Pelton Water Wheel Co. under the supervision of Mr. Christison.

The Pelton Water Wheel Co. was founded in San Francisco, in 1882, and has specialized in the design and manufacture of large hydroelectric turbines, valves and other equipment required by hydroelectric projects. The company has used welding for many years, having pioneered the use of fabricated parts in high-pressure hydro plants. The Los Angeles plant is largely devoted to welding while the San Francisco plant handles other phases of manufacture.

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Much of the work done in Los Angeles is highly specialized, requiring many intricate forming operations. As a matter of necessity and economy, the company has designed and made many of the machines required to perform this work.

Typical of some of their fabricated machinery is the 300-ton hydraulic press shown in Fig. 1. The main cylinder of this press is unusual in that this item is normally forged on most presses. This cylinder was rolled from 3-in. plate and welded at one seam. The head was made from 4-in. plate and welded to the cylinder. The throat of the press was made from 7-in. plate and the sides from 2-in. plate.

A machine that handles some of the other forming operations is seen in Fig. 2. The capacity of this plate forming roll is 1-in. plate 10 ft. long. Hydraulic cylinders actuate the $16^1/_2$ in. diameter top roll with 100 tons of pressure on each cylinder. The two bottom rolls are 14 in. in diameter with Hyatt roller bearings. The main members of this machine are $1^1/_2$-in. plate.

The welding of many of the large weldments made at Pelton is done on one of the largest positioners on the West Coast. In Fig. 3 one-half of a pressure tank for an oilfield hydraulic pump jack is being welded on the

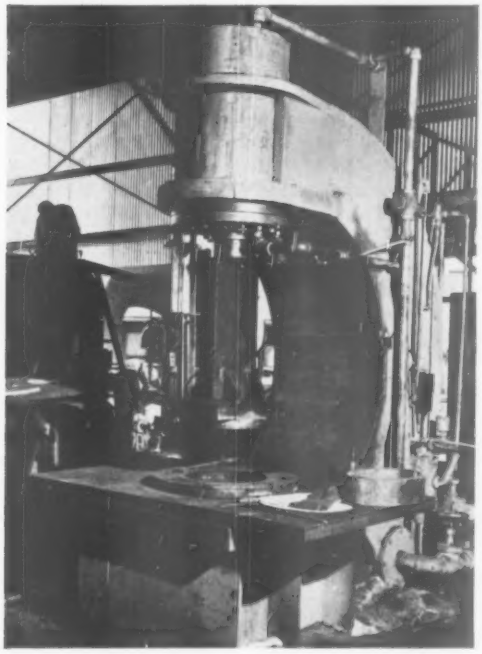


Fig. 1 A 300-ton fabricated press made by Pelton Water Wheel Co., Los Angeles, for forming work in heavy plate

The main cylinder of this press was fabricated from 3-in. plate, welded at one seam

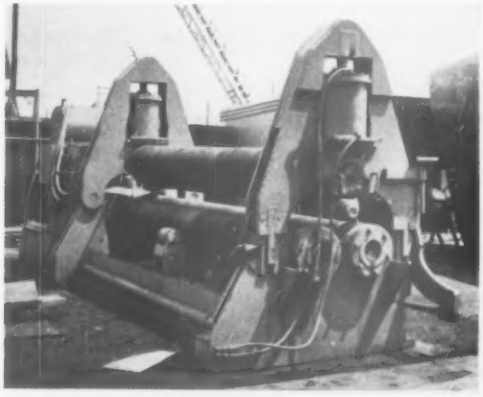


Fig. 2 Fabricated plate forming roll with a capacity for 1-in. plate up to 10 ft. long

Hydraulic cylinders actuate top roll with a pressure of 100 tons on each cylinder. The side members are $1^1/_2$-in. plate

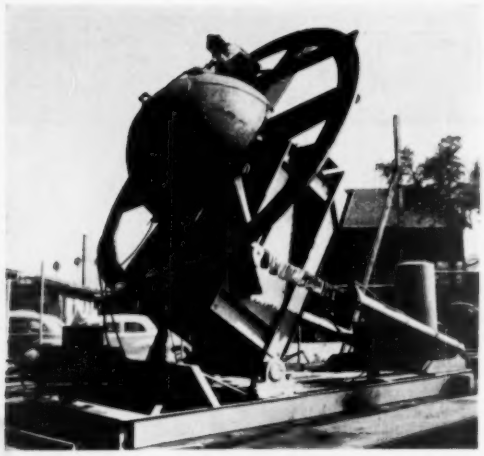


Fig. 3 Largest welding positioner on the west coast will hold 30 tons

Up, down and rotary movement is controlled from push-button box under operator's left hand. Vertical movement is hydraulically controlled

positioner. The operator controls up, down and rotary movement from a push-button box which is portable and is held in any desired place by an alnico magnet. The vertical movement of the positioner is controlled by hydraulic cylinders.

The table is made of 2-in. plate and the boxed spokes are made of 1-in. plate. The tilting frame is constructed from 12-in. I-beams with $^3/_8$-in. stiffener plates. It tilts on bearings with a 9-in. bore. The bottom frame uses 15-in. channels with 2-in. plate added for stiffness. The positioner will hold 30 tons.

The gantry made by Pelton for loading this outsize positioner is illustrated in Fig. 4. The tracks for the gantry run the length of the yard. Welding cables are crossed under these tracks through a pipe elbow which is embedded in the cement.

Another gantry recently installed is shown in Fig. 5. This is a 10-ton unit and was designed as a circular

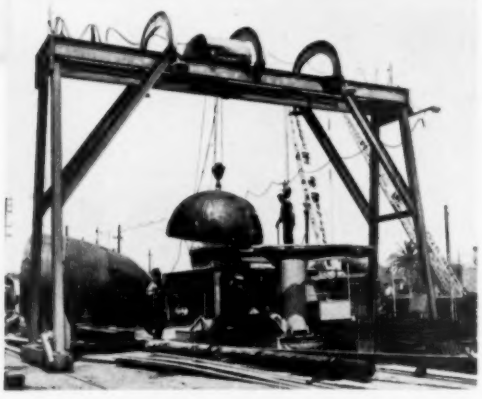


Fig. 4 Fabricated gantry for loading positioner

Fig. 5 Circular gantry designed to utilize remaining space in yard to best advantage

Has 10-ton capacity. Legs are made of 10-in. tubing

gantry to utilize the remaining yard space to best advantage. Traveling on rails made of 2- by 4-in. bar stock, the gantry covers a radius of 39 ft. 6 in. The legs are made from 10-in. tubing, the bridge from $^1/_2$-in. plate and roof mounted base of 6-in. stock. A 1-hp. geared reduction motor drives the crane wheels while a 10-hp. motor operates the hoist.

Typical of some of the specialized work handled by these fabricated machines is the spherical pressure tank

Fig. 6 Welding root pass on half sections of pressure tanks for hydraulic pump jack

Segments are 1-in. plate, scarfed for a 60° vee weld

for the hydraulic pump jack (Fig. 6). This tank is made of 1-in. plate and has an inside diameter of 7 ft. Each half of the tank consists of six segments and one "dollar" plate. The segments are formed on the 300-ton press shown in Fig. 1. The die attached to the ram is the one used for forming the segments.

The segments are welded with a stringer bead first (Fig. 6), using E 6010 electrodes for the root pass. The edges of all segments are flame scarfed for a 60° vee-weld. Next, the segments are placed on the positioner to allow positioning for flat welding with E6020 electrodes. A $^1/_4$-in. diameter electrode is used at 300 amp. After the outside is welded, the half section is removed and the inside of each weld is then flame gouged to clean the metal, then replaced on the positioner and the inside is finish welded.

The completed tanks are tested at 900 psi. for a working pressure of 450 psi.

Mechanized Silver Brazing

THERE are many times when it is desirable to set up a temporary production line to braze an item that is produced intermittently or seasonally. By mounting brazing torches on a moving carriage and positioning jig stations along the line of travel of the carriage, it is possible, by varying the setup of the torches and jigs, to silver braze a wide variety of products.

Figure 1 illustrates a setup for straight-line production. The track for the moving carriage is mounted on a welded-steel framework. Parallel to the track and positioned on the same framework are a series of jig stations to hold the product that is to be brazed. To supply the heat necessary for brazing, torches with flexible extensions and heating tips are mounted on a horizontal bar that is held in position by a vertical post on the moving carriage. The flexible extensions on the torches allow the heating tips to be adjusted to play the flame on any position along the line of jig stations. As the moving carriage moves down the line of jigs, the brazed pieces are removed and replaced by unfinished pieces. When the run on one item is completed, the jigs may be changed and production started on another.

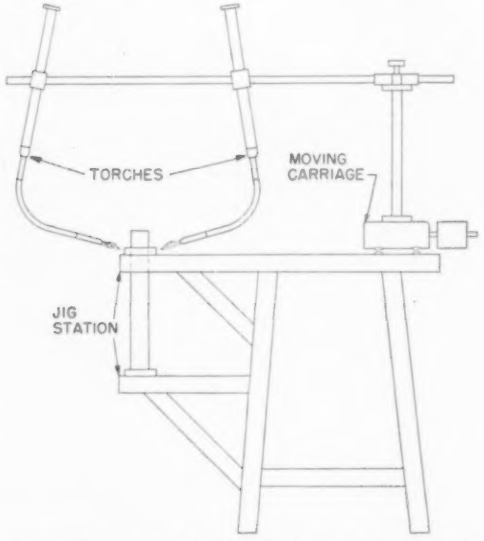
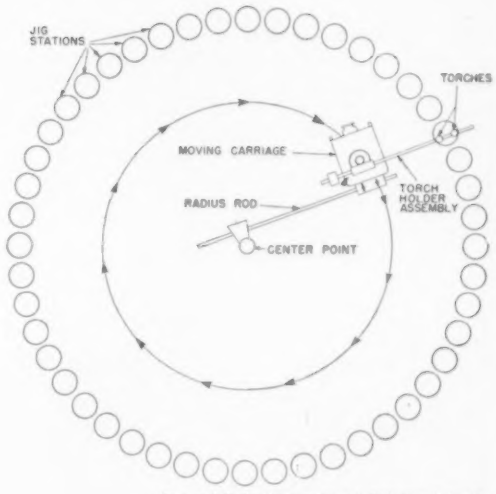


Fig. 1 Setup for straight-line production showing torch mounting arrangement, framework supporting jig stations and tracks for the moving carriage



Data and illustration courtesy Air Reduction Sales Co.

Fig. 2 Circular arrangement for mechanical silver brazing

Figure 2 shows the same system with a circular positioning arrangement employed to mount the jigs. In this arrangement the jigs are mounted on the outside diameter of a circular steel table. To control the circular motion of the moving carriage on which the brazing torches are mounted, a center point or bearing and a radius rod may be used to guide the carriage. With this setup, a continuous production line is possible.

Safe-Ending Drills and Chisels

by F. C. Geibig

UNLESS you give them a special treatment, the struck ends of chisels and similar hand tools will probably mushroom, crack or spall in a short time. Tools that look like those shown in Fig. 1 are dangerous to use. Any hammer blow is likely to send a steel chip flying off with considerable force. Or the hammer may slide off the edge of the end of the chisel onto your hand.

You can make these tools safe by rebuilding them with bronze welding rod. You will find that the striking ends of safe-ended chisels outlive those of untreated chisels. The bronze will wear but it will not chip or spall and you can rebuild them many times.

These pictures show how to do the job. Do not get the cutting end too hot or you will draw the temper. If you do a lot of safe-ending work you can build a jig like the one shown in Fig. 8.

F. C. Geibig is with The Linde Air Products Co., Newark, N. J.

Fig. 4 Make yourself a little holder like this from a welding rod. Heat the end of the chisel until it turns dark red, then deposit the molten metal on the shoulder. Use 1/8-in. bronze welding rod with plenty of flux

Fig. 1 These chisels are dangerous to use because the battered struck ends are badly spalled

Fig. 2 The first step is to cut away the damaged metal with your cutting blowpipe or cutting attachment

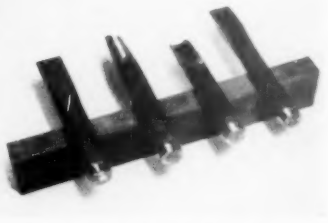


Fig. 3 Grind the ends down to sound metal and form a shoulder as shown in Fig. 6

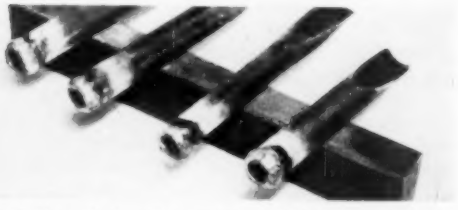


Fig. 5 Keep the heat low and the puddle small. Rebuild a section 1/2 in. wide then turn the chisel and build another section. The weld metal should be slightly higher than the rest of the chisel

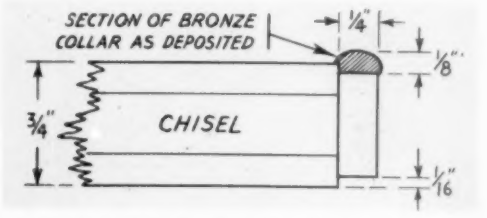


Fig. 6 After you grind a shoulder, as shown in Fig. 3, deposit a collar of bronze weld metal so the chisel looks like this. The shoulder dimensions are the same for all sizes of chisels

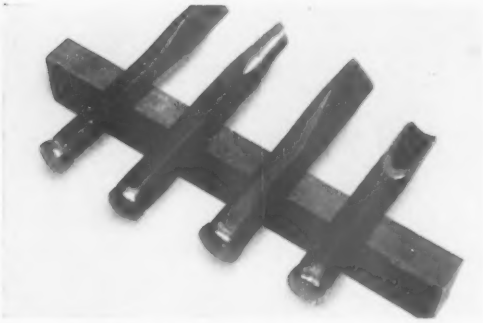


Fig. 7 Clean the weld metal with a wire brush. Then use a rasp or file to square the ends and smooth off the weld metal. One safe-ended chisel will outlast three ordinary chisels

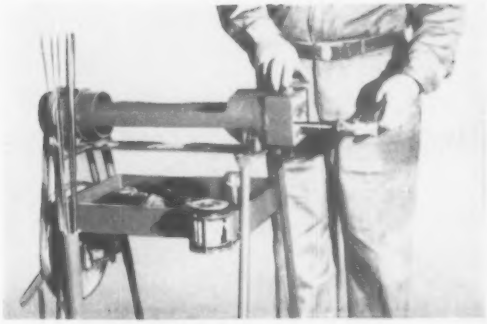
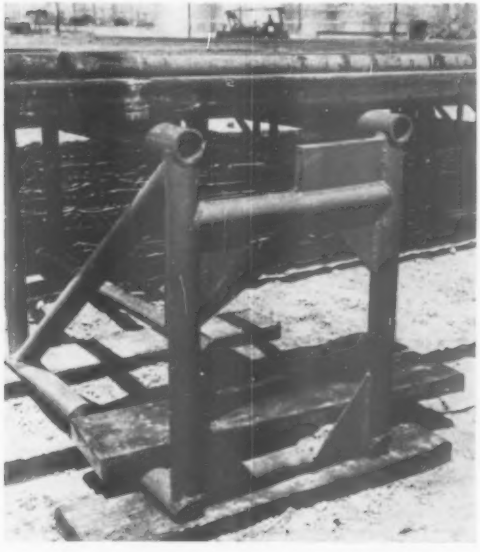


Fig. 8 If you do a lot of safe ending, you will find that a jig like this will save you a lot of time. Notice that there is room for your welding rod, flux and many of the tools you need

Welded Open-End Storage and Pipe Rack Sections Make Transferring of Material Easy

AN 8- by 13-in. opening is left in the top of each section of the storage and pipe rack assembly shown in the accompanying figure. A 12- by 12-in. timber then can be placed between racks in the slots and material transferred from one to the other quickly and economically.

The three section racks are 28–31 ft. long and spaced 9 ft. apart. They are of welded construction, made from discarded drill pipe.



Photograph courtesy The Lincoln Electric Co., Cleveland 1, Ohio

Cable Care

ONE way to eliminate the hazard of having welding cables severed by the wheels of traveling gantry is shown in the accompanying photograph. The pipe elbow embedded in the cement carries electrode cables under gantry track in the yard of the Pelton Water Wheel Co., in Los Angeles. Pipe elbow is grounded to welding positioner and connected to ground lead from welder.

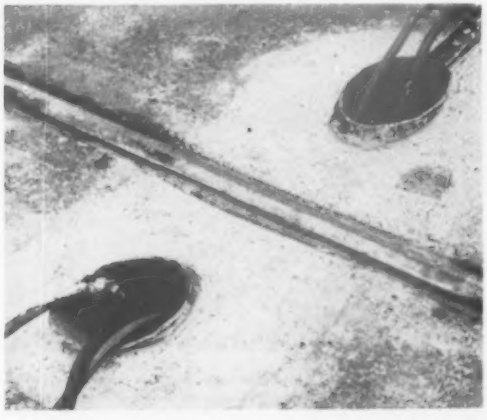


Photo courtesy The Lincoln Electric Co., Cleveland 1, Ohio

Convenience and Safety Devices for Oil Company Tank Farm

by Sam Bickley

AT A NEW tank farm of a West Coast oil company, a little ingenuity applied with an arc welder has produced some unique convenience and safety devices.

A convenient method of anchoring gathering lines on the farm prevents damage to instruments through vibration. Short lengths of salvage pipe, the same diameter of the lines to be anchored, are cut out to fit the contour of the line and placed upright in the ground under the lines (Fig. 1). To keep the lines nested in these upright pipes, two short lengths of threaded bolts are welded on the bracing pipe and passed through short pipe eyelets welded to the gathering lines. A nut tightened down on the threaded bolt securely anchors the line.

In a tank farm where many of the lines are above ground, it is imperative that working personnel have safe, easy access to the different working stations. One solution to this problem is illustrated in Fig. 2. An angle-iron frame fabricated in a shape that will bridge the lines is covered with expanded metal. The angle frame is cut out in several places to fit the contour of the lines to anchor it and is made with a gentle slope to it so that walking over it will be easy with a heavy load. Other expanded metal bridges are seen in the background of Fig. 2.

A convenient self-locking cellar door is shown in Fig. 3. This cleverly designed cellar door automatically locks in the open position allowing unhampered entry into the cellar. The concrete cellar with a steel top houses underground tank farm equipment. Access to the equipment is through this door, which is fabricated from walkway plate, and anchored at the rear by a hinge. The circular bar, which holds the door open, locks automatically as the door is thrown back.

A locking shoe automatically blocks the end of the curved bar when the door is opened, and prevents its sliding back down. The shoe is welded to a railing at the front of the entrance and because of the angle between the shoe and the mitred end of the pipe, it is impossible to lower the door without first tripping the shoe out of the way. A small bent bar welded to the shoe when raised with the hand or foot moves the shoe back out of the way so that the door may be closed.

A two-in-one proposition is shown in Fig. 4. A guard rail around a motor compressor unit serves also as a mounting for an oil reservoir drum. The one guard

Sam Bickley is welding engineer located at 1500 Calaona St., Los Angeles 23, Calif.

Data and photos courtesy of The Lincoln Electric Co., Cleveland, Ohio.

Fig. 1 Small pipe, tank farm gathering lines here can be anchored easily and securely by this simple operation of welding threaded bolts to bracing pipe and eyelets to the gathering lines

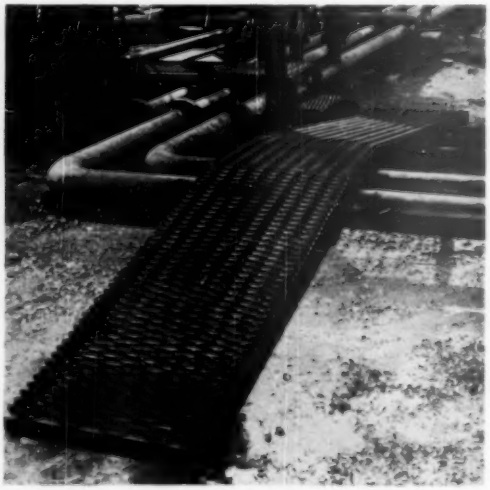


Fig. 2 Safety, particularly when carrying heavy loads, for working personnel on tank farms is provided by this angle iron frame covered with expanded metal

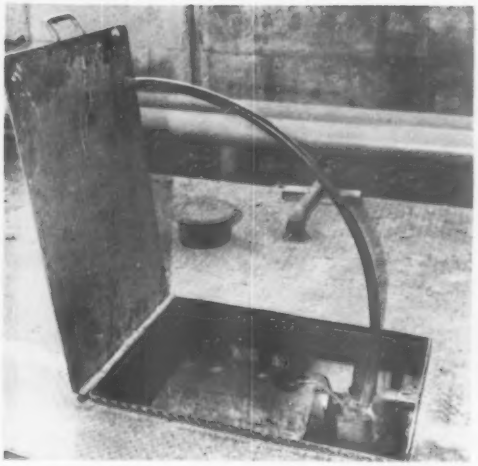


Fig. 3 A self-locking cellar door permits unhampered entrance to underground equipment on the tank farm

A locking shoe falls into place at the end of the curved pipe when the door is opened

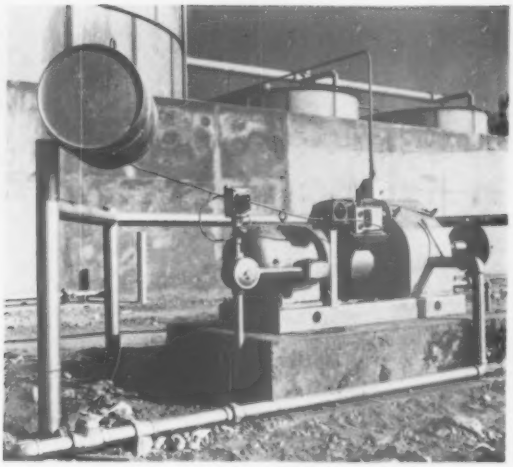


Fig. 4 Two-in-one purpose is served by the guard rail around a compressor unit

It also mounts a reservoir oil drum from which, by gravity flow, oil is fed to the compressor

rail was made higher than the others to permit using gravity flow from the reservoir to the compressor. Curved sucker rod welded to the pole cradles the drum from which a line is run to the compressor.

Two Ways to Make Sharp Edges When You Hard-Face

by H. G. Keitz

HERE are two ways to deposit hard-facing rod to get a sharp, square edge. Figure 1 shows a hard-faced steel part in its finished shape. To deposit hard-facing alloy so it will clean up with square edges like this, first deposit a layer of hard-facing rod along the edge.

The edge will round off, as shown in Fig. 2. Of course, its impossible to grind this part and have straight sides and a sharp corner. The hard-facing rod must flow over the edges as shown in Fig. 3. This is called "edge beading."

To get an edge like this point the blow-pipe flame directly at the edge. Only the surface of the hard-facing alloy you have just deposited should be melted. Hold the welding rod directly over the edge with the end of the rod in the flame and just about touching the metal. When the metal comes to the melting point start to deposit the rod metal. Add enough rod to form a bead slightly wider than the first layer.

Some time you may want to do away with edge beading and make it easier to control the weld metal. You can do this by making a groove of the proper width in the part to be hard faced. Leave a shoulder about 1/16 to 1/8 in. wide at each side as shown in Fig. 4. Then you can fill the entire grooved section to its proper height at one time. Figures 5 and 6 show how to cut off the shoulder and finish off the ends.

H. G. Keitz, The Linde Air Products Co. Newark, N. J.

Fig. 1 (left) This shows a finished steel part that has been hard faced along the edges

Fig. 2 (center) After the first layer of rod metal the edge will round off like this. A square corner will be impossible

Fig. 3 (right) Point the flame at the edge. Only the surface will melt and you can deposit another layer of hard-facing rod that flows over the edge

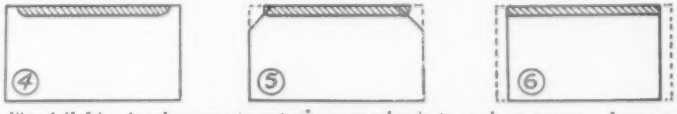


Fig. 4 (left) Another way to get a square edge is to make a groove. Leave a shoulder at each side

Fig. 5 (center) Fill the entire groove with hard-facing rod. Then cut off the shoulder like this or as shown in Fig. 6

Fig. 6 (right) This is another way to cut off the shoulder after you fill the groove with hard-facing rod

Photos courtesy The Lincoln Electric Co., Cleveland 1, Ohio

***Fig. 1** Labor-saving device for welding scrubber tanks*

***Fig. 2** Close-up of wheel assembly showing threaded bolt with nut welded to flange. Handle allows unit to be leveled quickly*

***Fig. 3** Slag scraper made from old file ground down on emery wheel*

Jig for Scrubber Tanks

A WELDER at the Superior Tank and Construction Co., Los Angeles, Calif., has devised several clever labor-saving contrivances to make his work easier in welding gas scrubber tanks. The homemade unit which holds the tank was fabricated as follows: The two horses or stands are made of channel iron braced with tubing. There are two sets of wheels which allow the welded item to be turned. The wheels, made of $^1/_4$-in. plate steel, are welded to a $^1/_4$-in. frame. To this frame a $1^1/_4$-in. threaded bolt is welded forming a T-shaped unit. The work may be leveled by simply turning the nut flange which rides on the threaded bolt. A short handle is welded to the bolt allowing quick rising or lowering of the wheels. A hole is bored in the center of each stand and a short piece of the bracing tubing welded underneath acts as a housing for the threaded bolt. The bracing tubing joins with this piece of housing to form a triangular brace. (Figs. 1 and 2.)

Figure 3 shows another ingenious tool for slag removal made by grinding down an old file.

Brazed Safety Rings Prevent Smashed Fingers

TO PREVENT smashed and torn fingers, many metal-handled tools, such as crowbars, clawbars and machine levers have rings painted around the handle to warn the user not to grip the handle below the ring. Many times, the painted ring is scratched off or so obscured by dirt that the user is not warned of the danger of gripping the handle below the danger point until his fingers are injured.

To prevent this, a $^1/_4$-in. diameter metal ring, brazed to the tool, may be used in place of the painted ones. This is done by heating a $^1/_4$-in. diameter welding rod and bending it around the handle to form a ring. The ring is then permanently attached to the handle by brazing. This type of safety ring is visible at all times, and should the user slide his hand up the handle without looking, the safety ring will stop it from passing into the danger zone.

Data and sketch courtesy Air Reduction Sales Co.

***Fig. 1** $^1/_4$-In. diameter welding rod brazed on metal handle to form safety ring*

the AMERICAN WELDING SOCIETY

activities • related events

Welding Metallurgy

Space and budget limitations have made it necessary for The Welding Journal Committee to discontinue the publication of "Welding Metallurgy" serially in THE WELDING JOURNAL. This should work no great hardship on readers of THE WELDING JOURNAL as copy of this valuable book is available in attractive book form with imitation leather covers and complete index at $2.50 per copy. This book contains 492 pages with 202 illustrations. Copies may be ordered by writing to AMERICAN WELDING SOCIETY, 33 W. 39th St., New York 18, N. Y.

Welding Handbook

The Third Edition of the *Welding Handbook* recently made available is receiving wide acclaim. Orders are being filled as rapidly as possible. Members desiring a copy of the book should get in their orders as soon as possible.

List price per copy is $12 in the United States and Canada, $13 elsewhere. Additional copies at $9.00 each to members of the SOCIETY.

Order your copy through the AMERICAN WELDING SOCIETY, 33 W. 39th St., New York 18, N. Y.

Annual Meeting Program

The Annual Meeting Program is shaping up to be the largest in the history of the AMERICAN WELDING SOCIETY. Eighty-three papers are being scheduled. Three simultaneous sessions will be held every morning and afternoon, except Wednesday and Thursday afternoons. On these two afternoons, opportunity will be provided for members and their guests to visit the Show or to participate in the Inspection Trip which will be held on Thursday Afternoon. In addition to the large number of unusual technical papers, special sessions are provided on the tecanical activities of the SOCIETY, education and design. The President's Reception will be held on Sunday Afternoon. The Award of Prizes and the Adams Lecture will take place on Monday Evening. The University Research Conference will be held on Wednesday Evening. An open session on Resistance Welding will be held on Monday Afternoon.

Preliminary Program will be published in the July issue of THE WELDING JOURNAL.

Member-for-Member Drive Continues

The SOCIETY is continuing its Member-for-Member Drive. This provides an opportunity for every member to secure at least one new member thus increasing the membership by a type of member who is likely to benefit from the Society and continue his membership for a long time.

1950 Annual Meeting Oct. 22–27, 1950

Official Headquarters—Hotel Sherman, Chicago 1, Ill.

The 31st Annual Meeting of the AMERICAN WELDING SOCIETY will be held Oct. 22–27, 1950, in Chicago, Ill., with Headquarters at the Hotel Sherman, Randolph and Clark Sts.

Because of the large attendance anticipated, it is important that hotel reservations be made now. Your SOCIETY has been allotted by the Hotel Sherman a block of rooms which include single rooms, twin-bed rooms, double-bed rooms and suites consisting of parlor and one or two connecting bedrooms. We recommend that you fill out the yellow form being sent to all members and send it to the Hotel Sherman without delay. Please be certain to list your name if you are the occupant, or the names of those whom you will assign to the rooms. This will avoid duplication of reservations.

Eighty-two per cent of the rooms in the Hotel Sherman are twin-bed rooms. Therefore, we suggest that individuals double up, wherever possible, as they will stand a much better chance of securing satisfactory accommodations, if their requests call for rooms to be occupied by more than one person.

Reservations will be accepted in the order in which applications are received. Applications will be acknowledged promptly and when rooms have been assigned, you will receive confirmation from the Hotel Sherman with reasonable promptness. If confirmation is not received from the Hotel Sherman within thirty days after mailing your application please notify Hotel, *with copy to A.W.S. Headquarters.*

The Society's Annual Meeting will be held during the week of the 32nd National Metal Congress and Exposition which is scheduled for Oct. 23–27, 1950, at the International Amphitheatre, Chicago, Ill. We urge all A.W.S. members to attend both events and to apply immediately for their room reservations.

414 Attend Second AIEE Welding Conference in Detroit

Attendance numbered 414 at the Second Conference on Electric Welding held April 5–7, in Detroit, Mich. Technical sessions on arc welding, research and equipment, instrumentation, special welding processes and equipment and power supplies for resistance welding attracted personnel representing research groups, equipment manufacturers and users.

Most popular innovation at this Second Conference was evening demonstration sessions sponsored by the Detroit Section of the AMERICAN WELDING SOCIETY. Demonstrations and exhibits were presented by twenty-four companies active in the electric welding field. Inert-gas-shielded arc welding, flash welding, spot welding, stud welding and measurements were among the subjects for which latest equipment and techniques were presented.

Sponsorship of the Conference was by the American Institute of Electrical Engineers acting in cooperation with the AMERICAN WELDING SOCIETY and the Industrial Electrical Engineers' Society of Detroit.

200 Firms Already Signed for 1950 Metal Show

The 32nd annual National Metal Congress and Exposition—the Metal Show—which opens in Chicago's International Amphitheatre on Oct. 23, 1950, is already well along the way to becoming the largest and most significant of them all. This year's event, covering the Metalworking industry's need for greater economy in unit production, has, to March 20th, assigned exhibit space to 200 of the country's leading firms, with daily requests from others who will be among over 350 companies expected to have displays of their products, equipment and services during the five-day Show.

Four National technical organizations will again sponsor the Metal Show in 1950. In addition to the managing sponsorship of the American Society for Metals, the other three sponsors will be: The AMERICAN WELDING SOCIETY; The American Institute of Mining and Metallurgical Engineers—Metals Branch; and the Society for Nondestructive Testing.

Managing Director of the Metal Show: W. H. Eisenman; Assistant Director; Chester L. Wells. Executive Headquarters, 7301 Euclid Ave., Cleveland 3, Ohio.

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NEWS OF THE INDUSTRY

S.E.S.A. Meeting

The Spring Meeting of the Society for Experimental Stress Analysis will be held at The Hotel Statler, Cleveland, Ohio on May 25–27, 1950.

Inquiries should be addressed to the Society for Experimental Stress, Analysis, P. O. Box 168, Cambridge 39, Mass.

53rd Annual Meeting American Society for Testing Materials in Atlantic City, Week of June 26

A large number of technical papers and reports, including several symposiums, will be presented at the Fifty-Third Annual Meeting of the American Society for Testing Materials in Atlantic City throughout the week beginning June 26, 1950. During this week the Ninth Exhibit of Testing Apparatus and Related Equipment will be in progress, and the Society's Biennial Photographic Exhibit.

American Welding & Mfg. Wins Safety Award

The American Welding & Manufacturing Co. joined the ranks of the elite of industry today when it received a second Distinguished Service to Safety Award from The National Safety Council. Only 99 companies in the entire country have ever received this second award.

At ceremonies held on March 21st in the company's plant, at Warren, Ohio, President William J. Sampson, Jr. received the award, a hand-decorated scroll, from R. H. Ferguson, executive board representative of The National Safety Council and Manager of Safety of the Republic Steel Corp. Ferguson also presented the National Safety "S" Flag with Star jointly to Leo Dunlap, General Foreman, and George Fuchilla, President of C.I.O. Local 1574, representing the workers of American Welding.

A.S.T.M. Committee A-1 on Steel

For several years Committee A-1 on Steel has recognized the need for mechanical testing manuals covering the various fields of steel products. Much work has been conducted on preparing such manuals and several are now in their final stages. It is recommended that each be published as an A.S.T.M. document; but the various manuals will finally be combined in one document.

In 1949 the Society published a special pamphlet including the ten specifications for structural steel written by Subcommittee II including the new General Requirement Specification A 6. The yield point and elongation requirements in all the structural steel specifications have been reviewed and correlated so that definite figures will be included in place of the old sliding scale figures. With the incorporation of these revisions, structural steel specifications will be advanced to the status of standard with the exception of A 131 covering ship steel, on which work is in progress.

Editorial revisions in Specification A 53 for welded and seamless steel pipe were approved by Subcommittee IX, including a proposal to clarify the marking for Bessemer pipe. Also in Specifications A 83, which includes lap-welded iron boiler tubes, it is proposed to clarify the chemical composition on the alternate type B open-hearth iron by stating that it may be produced with a copper content of 0.20 max. or with a molybdenum content of 0.05 to 0.15 and copper 0.40 minimum.

In subcommittee XI covering steel for boilers and pressure vessels, a new specification covering 1% chromium, $^1/_2$% molybdenum steel plate is being drafted.

In 1949 Specifications A 157-44 for Alloy-Steel Castings for Valves, Flanges and Fittings for High-Temperature Service, and A 217 for Alloy-Steel Castings Suitable for Fusion Welding for High-Temperature Service were consolidated into a new specification, A 217-49 T, covering ferritic grades. Since several austenitic grades were included in A 157-44 there is a need for a new specification covering these new grades and a group has been appointed to draft such a document.

In 1949 a tentative revision of Specifications A 234 for Factory-Made Wrought Welding Fittings was published which included the 1% chromium, $^1/_2$% molybdenum grade of material. It is proposed to include this tentative revision in the body of the specification. It has also been brought to the attention of Committee A-1 that there is a need in industry for a specification for stainless steel welding fittings to be used in conjunction with the stainless steel pipe covered by Sectional Committee B-36. The drafting of specifications covering this product is under way.

A new specification is under way for fusion-welded alloy-steel pipe for high-temperature service. There is demand for this type of pipe in central power station installation for reheat and main steam lines of large sizes and heavy walls to eliminate the need for forged and bored pipe which is very expensive. Several alloy grades of compositions now prevalent in high temperature use would be included, such as $^1/_2$% chromium; $^1/_2$% molybdenum, 1% chromium; $^1/_2$% molybdenum, $2^1/_2$% chromium and 1% molybdenum.

Specification A 312-48 T for Seamless and Welded Austenitic Stainless Steel Pipe is being revised to make it more satisfactory for use under the A.S.M.E. Boiler Construction Code. Among other revisions, supplementary requirements will be added including transverse tension tests, flattening tests, etching tests and statement that when formed by fusion welding, the procedure and the operators shall be qualified in accordance with the A.S.M.E. Boiler Construction Code. In addition, two new grades will be added to the specification, including types 309 and 310.

Officers of Committee A-1: *Chairman:* N. L. Mochel, Westinghouse Electric Corp., Philadelphia, Pa., and *Secretary:* H. C. Larson, Bethlehem Steel Co., Inc., Bethlehem, Pa.

A.S.T.M. Committee E-7 on Nondestructive Testing

To answer a very great need for radiographic standards for steel welds, Subcommittee II under the chairmanship of Alexander Gobus was organized in 1948 to establish a program for preparing suitable specimens and standard radiographic negatives. The entire program has now become a reality. Specimen blocks will be prepared by three cooperating companies including the Babcock and Wilcox Co., Combustion Engineering-Superheater Co. and the M. W. Kellogg Co. These blocks will become the permanent property of the A.S.T.M. Radiographic negatives of the blocks will be prepared through the entire range of standard X-ray equipment, including also Cobalt 60 radiation. This information was announced during A.S.T.M. Technical Committee Week held from Feb. 27 to March 3, 1950, in Pittsburgh, Pa.

A method for magnetic particle testing of steel castings is being considered in Subcommittee III under the chairmanship of Hamilton Migel. The present A.S.T.M. document relating to this subject is the Tentative Method of Magnetic Particle Testing and Inspection of Commercial Steel Castings (A272-44T). Method A 272 included descriptions of the various procedures applicable to magnetic particle testing of steel castings. While this document has served a very useful purpose for a number of years, many people in the steel casting industry feel that a more definitive method can now be written in view of the wide experience with this non-destructive testing tool during the last war.

Committee E-7 will sponsor a papers session during the A.S.T.M. Annual Meeting in Atlantic City with the theme to be "The Rôle of Nondestructive Testing in the Economics of Production." The papers will touch on both the engineering and managerial aspects of nondestructive testing with the following subjects proposed:

1. Principles and Mechanics of the More Important Nondestructive Test Methods.
2. Typical Discontinuities and Their Metallurgical Origin.
3. The Economics of Casting Inspection.
4. The Economics of Weld Inspection.
5. The Economics of Wrought Products Inspection.

The speakers will be recognized authorities in their particular fields.

Committee E-7 is also planning to participate in the Photographic Exhibit to be held in conjunction with the Annual Meeting. Many interesting exhibits tying together the results of the various methods of nondestructive testing will be shown.

Officers of Committee E-7: *Chairman:* J. H. Bly, Pratt & Whitney Aircraft, Division of United Aircraft Corp., Hartford, Conn., and *Secretary:* D. T. O'Connor, Naval Ordnance Laboratory, White Oak, Silver Spring, Md.

Steel Pipe Mill

The $5,000,000 Houston plant of A. O. Smith Corp. of Texas, which will manufacture large diameter welded steel pipe for the oil and gas industries, is being rushed to completion and will go into production about August 1st, D. F. McCarthy, vice-president of the firm, announced.

The plant has a heavy backlog of orders and will begin operation on a two-shift basis, with 25 production days a month, Mr. McCarthy said. It will employ more than 400 persons, including some 50 office and supervisory workers.

New facilities under construction at the nearby Sheffield Steel plant, which will supply a substantial part of the plate for the pipe mill, will provide jobs for an additional 200 employees, according to F. Ray McFarland, manager, Houston Division of Sheffield Steel Corp.

The pipe mill is owned jointly by A. O. Smith Corp. of Milwaukee and Sheffield, a subsidiary of ARMCO Steel Corp.

Included in the backlog of orders is pipe for 1000 miles of 30-in. transmission line which will move natural gas from the Houston area to Chicago. With its capacity of 35,000 tons of pipe per month, the new mill should fill this huge order in from $10^1/_2$ months to a year, Mr. McCarthy said.

Work on the plant and office building is being pushed on an around-the-clock basis by The Austin Co., of Houston and Cleveland, Ohio, who were awarded a contract last October for design and construction of the plant and installation of its massive machinery.

The main plant is 200 by 675 ft., with 135,000 sq. ft. or nearly three acres of floor space. Clearance of 33 ft. will be maintained below the trusses in the plant, which will have two 80-ft. craneway aisles,

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each equipped with two 20-ton cranes, and an intermediate 40-ft. aisle, all extending the full length of the plant. The "pickling building," 200 by 80 ft., adjoining the larger structure, will be equipped with a 40-ton crane, which will also serve a 330-ft. crane runway.

The manufacturing process in the new plant is ingenious and requires a high degree of skill.

Special skelp or plate will move to the pipe mill on rail cars from the Sheffield plant. After chemical cleaning or "pickling," edges of the plates will be trimmed and flattened. Heavy machines will then convert the flat plates into steel cylinders in three steps, the first machine making the plates U-shaped, the second crimping them into an egg shape and the third making them cylindrical. Another massive machine will then flash-weld the steel cylinders simultaneously over their entire 40-ft. length, without use of electrodes or welding rods, the original metal being fused.

The steel cylinders, as they emerge from the flash welders, will be somewhat smaller in diameter than ultimate size of the finished pipe. After trimming and cleaning, the pipe will be internally sized to its specified diameter.

Hauling away the plant's output in railroad cars will be quite an impressive operation in itself. The plant's output of 35,000 tons per month breaks down into 15,000 to 17,000 individual pieces of pipe, depending on diameter, each 40 ft. long and weighing better than two tons. In a month, the plant will turn out 680,000 ft. or 129 miles of pipe.

Eleven pieces of 30-in. pipe fill an average gondola car. The plant will fill 75 cars a day or 1545 cars a month. It will take a train three-fourths of a mile long to haul away the approximately six miles of 30-in. pipe which the plant will turn out in an average working day.

The Fulbright Program

Five New Countries Expected To Initiate Fulbright Programs in the Near Future

It is expected that Fulbright programs of international educational exchange will be initiated in the near future with Australia, Egypt, Iran, Turkey and India since an agreement has been signed recently with each of these countries. Any person wishing to apply for an award as advanced research scholar or visiting lecturer in any one of these countries is encouraged to write the Conference Board Committee at this time. An application form and necessary information will be sent to interested individuals by the Conference Board Committee as each program is inaugurated.

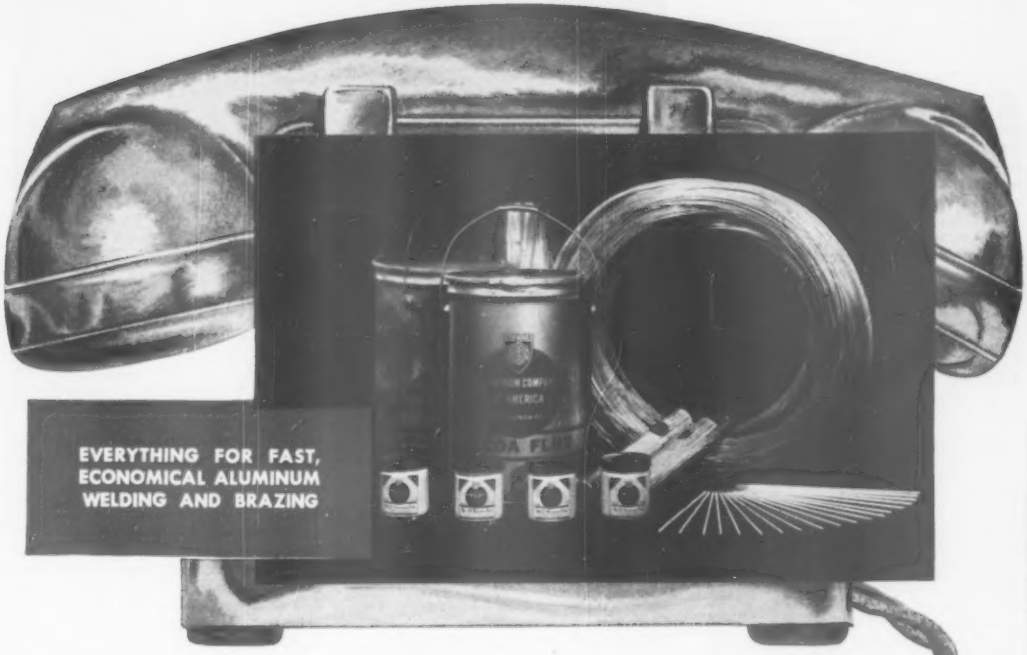
Invitations to Foreign Lecturers Encouraged

University and college administrators and heads of departments may be interested to know that there may still be time to work out orrangements under the Fulbright program for foreign lecturers to teach in their respective institutions during the academic year 1950–51. Since Fulbright awards to foreign nationals are made in the currency of their own country and cover only the cost of travel to and from the United States, it is necessary for them to secure dollar support from other sources for living expenses and travel within the U. S. Invitations to teach in universities and colleges will enable more scholars in Fulbright countries to apply for an award, thereby increasing the benefits of the program to the foreign countries and also enriching the academic life of this country.

Invitations to foreign scholars may be issued in either of two ways. An American university or college may invite a particular professor or a research scholar known to the institution to serve on its staff. In this case the institution is expected to advise the foreign scholar to file an application for a travel grant with the U. S. Educational Commission which administers the program in his own country. Upon the recommendation of the U. S. Educational Commission, the application is then forwarded through the Department of State to the Board of Foreign Scholarship for final action. Or a university or college may utilize the facilities of the Fulbright program to find a qualified person to fill a particular opening. Inquiries regarding the procedure to be followed in this latter instance should be addressed to the Conference Board Committee.

Application Forms and Programs for 1951–52 Will Be Available in Late Summer

Application for an award in the United



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If there is no Alcoa Distributor near you, write ALUMINUM COMPANY OF AMERICA, 1944E Gulf Building, Pittsburgh 19, Penna.

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Kansas City, North, Missouri
- Metal Goods Corporation

Los Angeles, California
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- Pacific Metals Company, Ltd.

Milford, Conn.
- Edgcomb Steel of New England, Inc.

Newark, New Jersey
- Whitehead Metal Products Co., Inc.

New Orleans, Louisiana
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New York, New York
- Whitehead Metal Products Co., Inc.

Philadelphia, Pennsylvania
- Edgcomb Steel Company
- Whitehead Metal Products Co., Inc.

Pittsburgh, Pennsylvania
- Williams & Company, Inc.

Portland, Oregon
- Pacific Metal Company

Rochester, New York
- Braco-Mueller-Huntley, Inc.

San Francisco, California
- Pacific Metals Company, Ltd.

Seattle, Washington
- Pacific Metal Company

St. Louis, Missouri
- Metal Goods Corporation

Syracuse, New York
- Braco-Mueller-Huntley, Inc.
- Whitehead Metal Products Co., Inc.

Toledo, Ohio
- Williams & Company, Inc.

Tulsa, Oklahoma
- Metal Goods Corporation

Kingdom and British Colonial Dependencies, Belgium and Luxembourg, France, Greece, Italy, The Netherlands, Burma, The Philippines, New Zealand and Norway for the academic year 1951–52 may be made in the late summer or early autumn when the programs for that year are available. At that time application forms and information regarding the appropriate program will be sent to all individuals who have expressed an interest in making application for an award in one or more of the foregoing countries. It is too late to apply for an award in these countries for the academic year 1950–51.

For Additional Information regarding awards to visiting lecturers and advanced research scholars, inquiries should be addressed to the Executive Secretary, Committee on International Exchange of Persons, Conference Board of Associated Research Councils, 2101 Constitution Ave., Washington 25, D. C.

Photo courtesy of Lincoln Electric Co.

Transcontinental Pipe Line

"In the Good Old Summer Time" . . . beside a babbling brook on the fourth spread of the Transcontinental Pipe Line in Alabama. The going has not always been so pleasant, however, on this line which is the largest pipe-line project in the history of the gas industry. The line stretches from the lower Rio Grande Valley to the Hudson River with a second terminus in Greenwich, Conn. The completed line will involve laying 1876 miles of main trunk line, to be finished in 1951 at a cost of $242,000,000. The line will serve, it is estimated, over four million users of natural gas in the Middle Atlantic area. Of the huge sum of money required to finance this project, not one cent was borrowed from the government. This is an undertaking of private capital raised by the Transcontinental Gas Co. through regular means of stocks, bonds and notes.

This spread in Alabama is some of the 1500 miles of 30-in. pipe in the line. Contractor is Midwestern Construction Co. The 30-in. pipe has a minimum yield strength of 52,000 psi. and was welded on this spread with $^{5}/_{32}$-in., E-6010, on the stringer and cap beads and with $^{3}/_{16}$-in. E-7010, on the filler beads. Joints were tested for 800 psi. pressure.

Welded "Dream Stadium"

City recreation officials in Detroit recently studied new plans of an all-welded rigid frame design of 200 ft. clear span. Its beauty had such appeal that it was publicized as a "Dream Stadium" in the Detroit News also the most modern building of its kind anywhere.

The plans show a $900,000 indoor ice arena that would seat upward of 5000 people and which could be used also for every other kind of public event. Of

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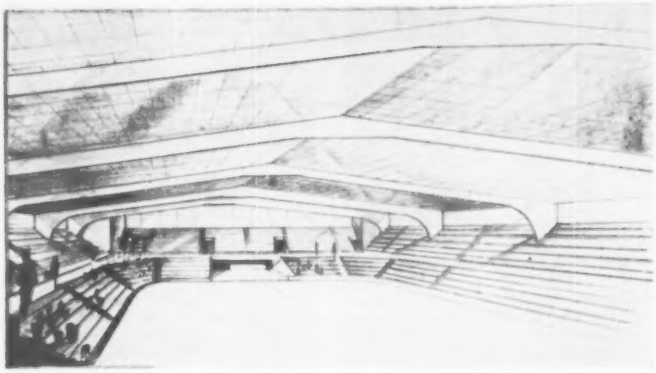


special interest were the simple and clean steel ribs without rivets, the result of welding.

According to General Superintendent John J. Considine of the Parks and Recreation Dept., the stadium would be a wonderful thing for the city. An expert has estimated that it would yield approximately $75,000 excess of income over expenses annually. However, for lack of funds at present, it will be fitted into the planning for the future.

The graceful effect and interior beauty are revealed in the architectural rendering made from the design of Martin P. Korn, Consulting Engineer, by Giffels & Vallet, Inc. & L. Rosetti, Associated Architects & Engineers, Detroit.

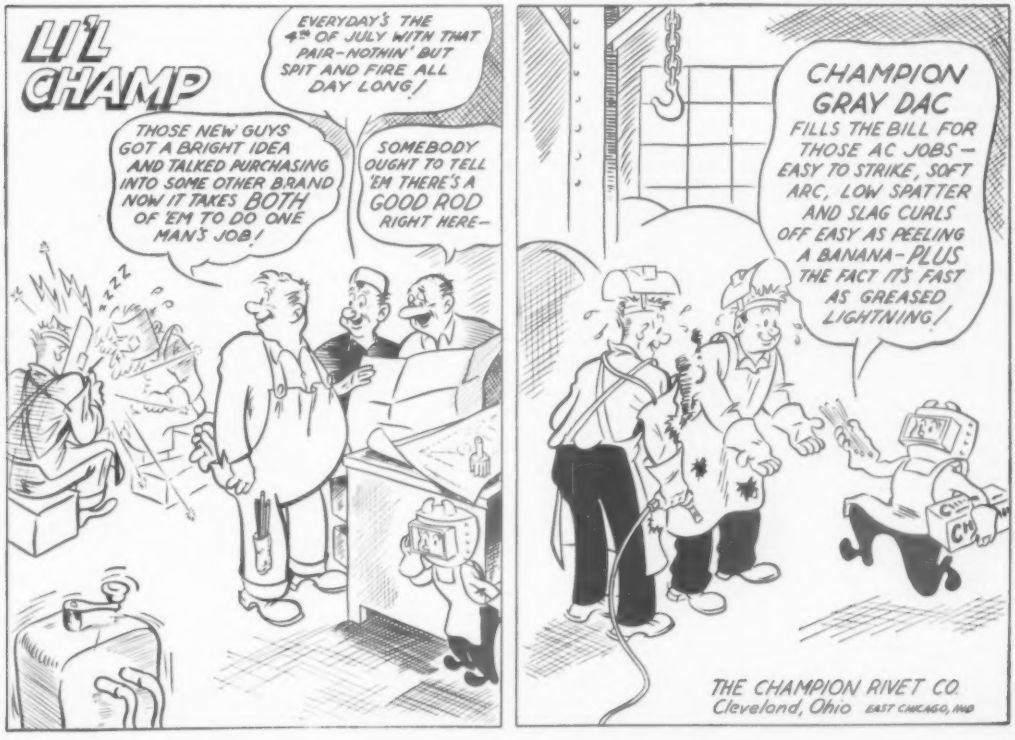
Nondestructive Testing Symposium

A symposium to acquaint engineers and management with the advantages and uses of nondestructive testing will be held June 27th at Atlantic City during the annual meeting of the American Society for Testing Materials. Sponsored by A.S.T.M. Committee E-7 on Non-Destructive Testing, the theme of the one-day conference is to be "The Role of Non-Destructive Testing in the Economics of Production."

Papers by leading authorities in the field will survey the wide range of applications of all the nondestructive testing and inspection methods and will show how proper use of them can reduce production costs and improve product quality.

Down on the Farm

This smokestack, 24 in. in diameter and 50 ft. high, newly erected at the Mt. Upton, N. Y., plant of the Sheffield Farms Co., Inc., was made for long-time, trouble-free service by the Erie City Iron Works of Erie, Pa., by bending wrought iron plates into cylinders and welding them together. Wrought iron, because of its well-known resistance to corrosion and fatigue, was chosen to replace a 10-gage stack that had been in use for 10 years.


LIL CHAMP
EVERYDAY'S THE 4TH OF JULY WITH THAT PAIR-NOTHIN' BUT SPIT AND FIRE ALL DAY LONG!
THOSE NEW GUYS GOT A BRIGHT IDEA AND TALKED PURCHASING INTO SOME OTHER BRAND NOW IT TAKES BOTH OF 'EM TO DO ONE MAN'S JOB!
SOMEBODY OUGHT TO TELL 'EM THERE'S A GOOD ROD RIGHT HERE—
CHAMPION GRAY DAC FILLS THE BILL FOR THOSE AC JOBS— EASY TO STRIKE, SOFT ARC, LOW SPATTER AND SLAG CURLS OFF EASY AS PEELING A BANANA—PLUS THE FACT IT'S FAST AS GREASED LIGHTNING!
THE CHAMPION RIVET CO.
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NEW LITERATURE

1949 A.S.M.E. Boiler Construction Code

This is an indispensable reference (published March 1950) for those who design, construct, install, inspect and use boilers and pressure vessels. The Code is issued in the following nine sections with all changes and additions of the past three years incorporated in its pages.

Power Boiler Code Including Rules for Inspection (Section I and VI), $2.75
Material Specifications (Section II), $5.00
Boilers of Locomotives (Section III), $1.00
Low-Pressure Heating Boiler Code (Section IV), $1.00
Miniature Boiler Code (Section V), $0.75
Suggested Rules for Care of Power Boilers (Section VII), $1.25
Unfired Pressure Vessel Code (Section VIII), $2.25
Welding Qualifications (Section IX), $0.90

The American Society of Mechanical Engineers 29 W. 39th St., New York 18, N. Y.

Report on Oil Engine Power Cost—1948

The information (published December 1949, $2.50) in this latest Report was supplied by 124 oil generating stations containing 441 engines which generated 721,347,430 net kwhr.

This Report has been compiled by the Subcommittee on Oil Engine Power Cost of the A.S.M.E. Oil and Gas Power Division for the purpose of providing engineers with a yardstick with which to compare the efficiency of their plant operations with that of others.

Shielded Stud Welding

The Shielded Stud Welding Co., 124 E. Fourth St., Los Angeles 13, Calif. has issued a four-page brochure giving technical information on aluminum stud welding; describing the process, its advantages, applications and acceptance. Copy available on request.

Low Melting Alloy for Cast Iron

A white-metal alloy which begins to bond at the exceptionally low temperature of 354°F. is being increasingly used for sealing cracks and building up defects on cast iron and other metals. This recently introduced welding rod is called EutecRod 15 and is made by the Eutectic Welding Alloys Corp., 40 Worth St., New York 13, N. Y. A new free bulletin, EU-3, describes and illustrates several case histories of the remarkable savings made possible with this rod.

Heliarc Literature

A new folder describing the main features and specifications of Heliarc apparatus now available, has recently been published by The Linde Air Products Co. Equipment illustrated includes the following: five models of the torch for manual and mechanized operation, new argon regulator and argon flowmeter, especially designed to give accurate gas flows, ceramic and water-cooled shielding-gas cups, electrodes and the argon-water shut-off valve.

Advantages of the inert-gas-shielded arc-welding process and the metals for which it can be used are described as well as the theory of the process.

This folder, "Inert-Gas-Shielded Arc-Welding Equipment," F-7013 is available on request to The Linde Air Products Co., offices in principal cities throughout the United States, or write to the general office, 30 E. 42nd St., New York 17, N. Y.

Metallizing Saves Money on Turbine Repairs

The current issue of the Metco News shows how metallizing saves money on turbine repairs. For instance, at the BMT Power House in Brooklyn, erosion had taken place on the casing between the last four rows of stationary blades of a 20,000 kw. Westinghouse steam turbine. It was decided to metallize only one end of the turbine with stainless steel and to operate it one year, after which the coating could be inspected to determine whether the other end should be sprayed. One year later when the turbine was inspected the sprayed coating was carefully sounded and found to be perfect. The general appearance of the coating was that it had just been applied; there was no sign of erosion or corrosion. The other end was then sprayed. Inspection five years later showed the coating on both ends of the turbine to be in first class condition.

Another metallizing user repaired a leaking gland case of a 2500 kw. bleeder-type steam turbine in 16 hr. The eroded spindle gland case threatened to result in complete failure. Replacement would have caused extended shutdown and the repairs could not be made by welding since excessive heat would warp the case. The case was removed, grooved, grit blasted, metallized with stainless steel and machine finished. The job took less than 16 hr. User states, "The cost of the replacement would have been one hundred times more than that for the time and material required in metallizing."

One of the largest manufacturers of turbines has adopted metallizing as a means of improving their products. Other metallizing applications are air hose couplings, axle shafts, brake drums, journals, pistons, spindles, etc. Write for your copy of Metco News Volume 5, No. 1, Metallizing Engineering Co., Inc., 38-14 30th St., Long Island City 1, N. Y.

Brazing Ring

An illustrated case history showing and describing application of new patented-notched coil stress-relieved silver alloy brazing and soldering rings in the manufacture of refrigerant gas strainers for household refrigerators has been made available by the Lucas-Milhaupt Engineering Co., 5057 South Lake Drive, Cudahy, Wis., manufacturers and distributors of silver-alloy preforms and specialties.

Fully illustrating advantages of the new rings over conventional preforms in design and application, literature shows how this particular manufacturer increased hourly production by 800% and reduced operating costs by 75% over previously used conventional methods. Rings can be detached from coil easily without breaking or distortion and fit snugly over outside diameter, automatically lap themselves or can be compressed for use in inside diameters. Tolerances of plus and minus 0.001 in. in actual ring diameter or developed wire length are maintained at all times and under all conditions. Copies of case history can be obtained from the manufacturer.

Safety Bulletin

In an attempt to reduce the number of potential hazards in electric arc welding—one of modern industry's most versatile techniques—a new bulletin has just been published by the accident prevention department of the Association of Casualty and Surety Companies.

Because of its economy and flexibility, welding has, in many cases, taken the place of riveting, bolting and other forms of fastening metals together in the construction of aircraft, automobiles, trucks, ships, railroad cars, refrigerators, buildings, bridges and many types of tools and machinery.

"As with a number of other occupations," the introduction to the bulletin says, "there are certain inherent hazards encountered in electric arc welding which must be recognized and approached from the viewpoint of the casualty insurer. However, proper recognition is given to these hazards and suitable protection taken, the process is normally safe and the frequency of accidents and losses is no greater than with any other manufacturing process."

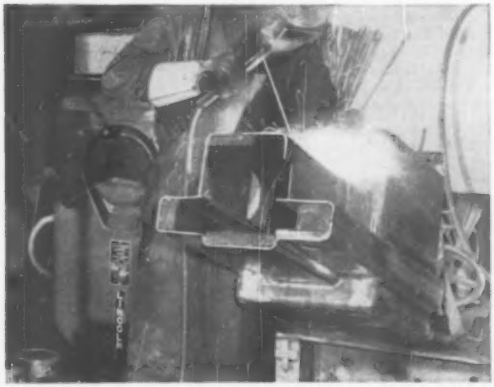
Some of the principal hazards referred to in the bulletin include electric shock, flying sparks and the possibility of inhalation of fumes containing harmful gases.

Copies of the newly-published bulletin are available through member companies of the Association.

How to Lick Arc Blow and other Problems too with the Lincoln A.C. Welder

By Duane Brady, Vice President
Welded Products Company
Grand Haven, Michigan

OUR production involves bases, brackets, tanks, sheet metal frames, small parts, heavy sections . . . an extremely wide variety of products. We have long and short welds, in-the-corner joints, plug welds, tack welds . . . the whole assortment.



Fabricating a base with the Lincoln 300 amp. "Fleetwelder".

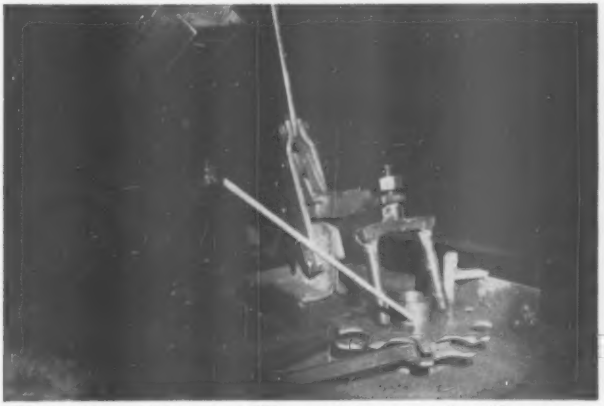
To beat competition, we need all the welding speed we can get and top quality welds on all of our wide variety of work.

Up until recently, we've been using Lincoln "Shield-Arc" Welders just about 100% because these D. C. welders certainly are versatile. Their Dual Continuous Control gives us the right arc for every job.

Then we got into a base job with considerable arc blow. We needed to lick the arc blow so we could use high currents and get faster welding . . . so we investigated A. C. welders for this job. Having tried A. C. welding many times, we knew it was good for some jobs but not for others.

We were surprised to discover that the Lincoln A. C. "Fleetwelder" not only licked the arc blow problem but did a swell job on many types of our work. It's "Arc Booster" and fine setting Continuous Control have certainly made A. C. welding a versatile tool.

Now, having both D. C. and A. C. welders, we can use the right type to get greatest productivity on every job.



The "Arc Booster" of the A. C. "Fleetwelder" gives speedy welding even on short beads for sprockets like this.

On heavy material or sheets, the "Fleetwelder" can be accurately set for easy, high-speed welding.

GET THE FACTS

Write for "Fleetwelder" Bulletin 366
THE LINCOLN ELECTRIC COMPANY
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LINCOLN

NEW PRODUCTS

Ipco Weldiscope

Industrial Products Co. announces a new, specialized welding shield designed for getting into offset or close places where the welder cannot normally see to make the necessary weld.

It comprises a conventional type of fiber shield to which has been adapted a form of periscope, improved in mechanical design to make it practical for the welding operation.

The welding shield, gives a true picture no reverse effect as experienced when using individually placed mirrors. It may be used for production welding in engine manufacturing, ship building, filling holes in castings and on other types of machines and materials.

For plant maintenance welding and commercial job welding shops doing repair work both inside and outside their shops it is not only a valuable aid in performing better work but a time saver. You know the welding has been done correctly as you can see it as well as if it were a surface welding operation.

Welding glass is on the inside where it is protected and is instantly turned out of the way of vision by means of a conveniently located trigger operated by the index finger of the same hand in which the shield is held. Welding glass automatically returns to welding position when trigger is released.

Both inside and outside opening of shield is protected by a clear cover plate.

A comfortable, offset fiber handle provides a secure grip and takes up minimum of space. Length, including the handle 18 in.

Full information may be obtained by writing to Industrial Products Co., 2832 N. Fourth St., Philadelphia 33, Pa.

Grinders

The Master Pneumatic Tool Company, Inc. of Orwell, Ohio has recently marketed two new additions to the Master Power line of portable pneumatic tools. They are two new models of short type heavy duty air-powered die grinders, called the Master Power M-612 and M-613.

The Model M-612 has a 1-in. spindle projection, threaded $^3/_8$ in.-24, weighing 3 lb. 6 oz., and is $9^{13}/_{16}$ in. in length overall. It may be fitted with a $^1/_4$- or $^1/_8$-in. collet for use with carbide and high-speed rotary files, as well as mounted abrasive points or a $^1/_8$-in. collet for using round abrasive sticks. The principal applications are general grinding of dies, cleaning of castings, deburring and cleaning or smoothing welds.

Flux

York Engineering Co., Chicago, announces the development of its standard "York's 77" into a 3-way all-purpose flux. It is now adapted for (1) general brazing, (2) cast-iron welding and (3) cast-iron brazing.

These new uses triple its advantages to users, giving them the important advantages of using one flux instead of three (avoiding the purchase of 3 individual types of fluxes) and a tremendous saving in time since only one can must be in use instead of three.

There is, too, the important matter of savings through avoidance of deterioration. With one can of "York's 77" 3-in-1 flux in constant use, there is little likelihood of loss—whereas, with three cans of different fluxes in use, the penalty of deterioration is greatly increased.

"York's 77" 3-in-1 flux is available through the York Engineering Co., 3349 W. Ogden Ave., Chicago 23, Ill.

Welded Wire Reinforcement

Pittsburgh Welded Wire Reinforcement is adaptable to all types of concrete construction. Among its many uses may be listed the reinforcing of roads, streets, sidewalks, driveways, runways, floors, roofs, canals, concrete pipe, gunite and, in fact, all concrete construction where it is necessary or desirable to avoid the disadvantages and dangers common to non-reinforcement.

Filler Metal

Eutectic Welding Alloys Corp., 40 Worth St., New York 13, N. Y., has brought out a number of new products. In respect to metal joining, the temperature range of around 700°F. is a critical one. For that is the "middle" range which is below the annealing point of most metals, and above the remelt temperatures of soft solders. EuteeRod 155, which has a bonding temperature of just 700°F., fills the need for a solder which operates at this medium temperature on both ferrous and nonferrous metals.

The new alloy has a tensile strength about half way between that of soft and silver solders, better corrosion resistance than soft solders and excellent wetting properties. Sizes available are $^1/_{16}$, $^3/_{32}$ and $^1/_8$-in. Further information may be obtained from Bulletin EU-30 which is free on request.

Troublesome cast-iron alloys can now be welded, with new high-strength machinable electrode.

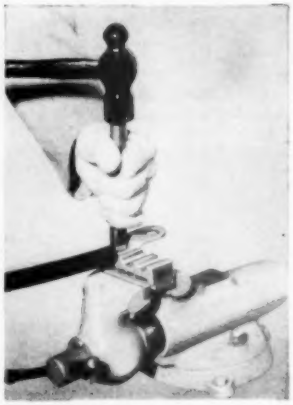
Eutectrode 25 "Formula 1950" gives welds of greater strength (60,000 psi.) and hardness (Brinell 210–250) and a close color match. Its patented FrigidArc coating eliminates the need for preheating. And because of its marked affinity for the parent metal, it readily welds corroded or rusty cast iron and heavy castings.

Eutectrode 2101 has by far the highest tensile strength of any aluminum electrode ever made—34,000 psi.—over three times that of conventional rods for this purpose.

Eutectrode 2101 "handles" almost as easily as a mild-steel electrode. Stop-and-start welding presents no difficulties. The weld puddle is visible at all times, because there is no blinding smoke to screen the work. No troublesome fumes.

"Lug-Set" Block and Punch

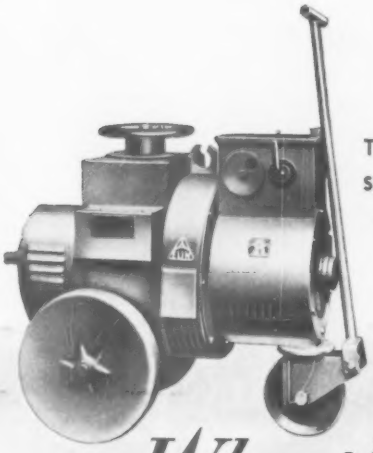
The Tweco "Lug-Set" consists of two simple tools which provide an easy method of attaching an ordinary copper soldering lug to a flexible cable. The set includes a special round end punch and a triple-saddle back-up block. The saddles of the block are designed to fit the barrels of the three sizes of Tweco Copper Soldering Lugs.



Copper soldering lugs applied with the Tweco Lug-Set give superior service over those applied by the old soft solder process with its low conductivity. Maximum conductivity is assured through the impacted high-pressure copper-to-copper contact of the lug barrel against the copper strands. Installed in one-fourth the time without heat or costly solder. Eliminates installation mess, scorched rubber, burnt strands, stiff joints and acid residue corrosion. No personal hazard in installing; no field failures from melting solder.

Tweco Products Co., Wichita 1, Kan.

SEE FOR YOURSELF . . .



TYPE **RFN 300**

Single Operator **Motor Driven**

60-375 amp **1750 rpm**

FULL NEMA RATING

Why the experts agree on ELIN

When you investigate the new ELIN D-C Arc Welder, you'll agree too that here's *perfected welding performance* . . . you'll understand why ELIN, first name in European welding equipment, is fast becoming the new word in America for welding at its best!

For here is the richest in both American and European welding experience — packaged in one machine.

Investigate ELIN efficiency . . . ELIN adaptability . . . ELIN endurance . . . ELIN economy. You'll see the many ways in which the ELIN RFN 300 means better welding for you.

Prompt delivery — spare parts in stock.

Territories still open for distributors.

Write for particulars.

Gives you all the facts!

Write for this bulletin today!

Presents THE CROSS FIELD PRINCIPLE—the operating principle that explains the ELIN Welder's positive performance.

Points out the efficiencies ELIN has captured through clean, compact design . . . lightweight portability, yet the stamina of two-bearing, low-speed (1750 rpm) operation.

Shows how ELIN has made welding almost effortless — through stepless, loss-free regulation . . . automatic voltage adjustment . . . clean-cut assurance of better welds, at greater speed, at less cost all the way!

american ELIN corporation

Welding Machinery Division

ONE WALL STREET • NEW YORK 5, N. Y.

WELD

You Save Rewelding Costs by Using Arcos Stainless and Low-Alloy, High-Tensile Electrodes

Arcos electrodes give you good, high quality welds, day after day, without the need for chipping and rewelding. That is because of the many rigid quality control inspections made during manufacture. And you can always pick the right electrode to give you the results you want from Arcos' complete line.

Arcos manufacturing processes are geared to the production of high quality electrodes to meet the exacting requirements of welding stainless and low-alloy, high-tensile steels, as well as non-ferrous metals.

Try an Arcos electrode on your next stainless or alloy welding job and measure your savings in less rewelding. All standard types and sizes available from near-by distributor stocks.

ARCOS CORPORATION
1500 South Fiftieth St., Philadelphia 43, Pa.

WITH ARCOS

Specialists in Stainless, Hydrogen Controlled, and Non-Ferrous Electrodes

Induction Heater

Electric-Arc, Inc., 152-162 Jelliff Ave., Newark 8, N. J., announces the availability of its redesigned Model BHD-S Smith-Dolan System Induction Heater.

This equipment has been engineered so that each half unit is energized independently by its own contactor. Voltage changes are made by a new rotary selector switch, so arranged that no changes are possible when the heater is carrying a load.

The pyrometer and the program controls have been engineered so that these controls can be switched to either half of the unit for control. And, in addition, it is possible to control both halves as one integrated unit.

General information about the functioning of the BHD-S Induction Heater is as follows. It is mobile and selfcontained, with fan-cooled units of 60 and 75 kva. It has a continuous rated capacity for heating 14- to 18-in. pipe welds to 1350° F. for stress relieving. An output of 125% of rating can be maintained for 2 hr. with safety.

Full information on the Electric-Arc line of induction heaters and control instruments for preheating before welding and stress relieving after welding may be obtained by writing to the manufacturer.

Welding Positioner

Welders save hours on heavy, bulky items with the help of the new Commando Positioner. This stout all-purpose clamp holds plow shares, bars, sheets and other shapes in rigid position while welding or working. The Commando Positioner

$125 and 7 weeks saved, thanks to NI-ROD repair of cast iron speed reducer

When a mishap all but destroyed a vital coil-vat speed reducer, maintenance men of the M & R Dietetic Laboratories were faced with a serious problem.

A new speed reducer cost 135 dollars and would take 8 weeks to be delivered. Repairing the unit would require only a week, but the damage was so extensive that success seemed doubtful. Yet, there was so much to be gained that they decided to take the gamble.

The shattered speed reducer was sent to M & R's welding shop, where . . . using Ni-Rod® electrodes . . . their welding technicians succeeded in assembling the broken pieces.

The cost of the repair, including labor, was only 10 dollars, and the time required was 1 week. *This represented a net saving of 125 dollars and 7 weeks down time. A highly profitable operation, indeed!*

Experiences such as this . . . of time and money saved in welding cast iron with Ni-Rod electrodes . . . are daily occurrences at thousands of welding shops throughout the nation. The reason for Ni-Rod's popularity with these experienced welders is *dependability*. With Ni-Rod electrodes you get quick, sound, machinable welds in all grades of cast iron . . . usually without preheating or postheating. Ni-Rod works well in all positions; can be used with either AC or DC current.

The best way to find out about Ni-Rod's many advantages is to try it. Order a package today and discover for yourself why *4 out of 5 shops* re-order Ni-Rod, once they have tried it.

Your nearest INCO distributor stocks Ni-Rod in 3/32", 1/8", 5/32", and 3/16" diameters.

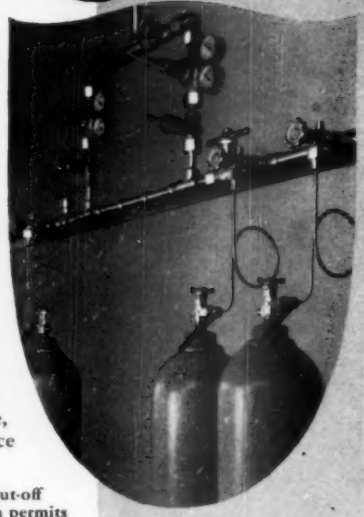
Coil-vat speed reducer repaired with Ni-Rod at M & R Dietetic Laboratories, Columbus, Ohio.

For welds you've never been able to make before . . . in high-phosphorous irons; heavy sections—

NI-ROD "55"

THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street, New York 5, N. Y.

REGO



MANIFOLDS

Rugged construction and precision control equipment give RegO manifolds long life, safe, dependable performance and low maintenance.

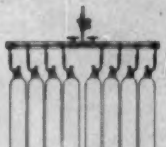
Continuous Operation . . . Shut-off valve at each cylinder station permits removal of any cylinder without shutting down entire side of manifold. Master valves control each bank of cylinders.

Unit Construction . . . Header consists of steel I-beam, extra heavy brass pipe and fittings, cylinder stations and master shut-off valves . . . *with all permanent connections silver brazed.*

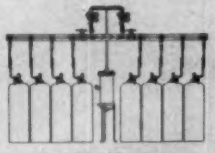
Precision Regulation . . . Uniform delivery pressure is assured by dual large capacity two-stage RegOlators.

Listed by Underwriters' Laboratories, Inc. and Factory Mutual.

Write for 24-page catalog giving complete specifications.



Typical Single Regulator Wall-Type Oxygen Manifold



Typical Dual Regulator Floor-Type Acetylene Manifold

for
OXYGEN
ACETYLENE
HYDROGEN
NITROGEN
and other high pressure gases

*Reg. U.S. Pat. Office

PIONEER AND LEADER IN THE DESIGN AND MANUFACTURE OF PRECISION EQUIPMENT FOR USING AND CONTROLLING HIGH PRESSURE GASES

The BASTIAN-BLESSING Company
4201 West Peterson Ave. Chicago 30, Illinois

holds items in any position needed for easiest welding, and can quickly be adjusted to new positions as the welding progresses. A plowshare, for example, can be welded on one side, then quickly flipped over to its other side without loosening it from the strong grip of the Commando Positioner. Makes welding easier, quicker and safer. The Commando Positioner is made of heavy cast steel with eyes drilled in its base for quick, secure mounting. Sliding bars on tightening nuts give extra leverage for secure tightening on all objects. Contact your welding supply distributor or write Ragle Industries, 4029 Indiana, Kansas City, Mo.

Heliarc Welder

The Miller Electric Mfg. Co. of Appleton, Wis., announces a new a.-c. arc Welder for "Heliarc" welding with fast, hydraulic amperage control.

This new, field-tested hydraulic amperage control enables the operator to make instant amperage changes without leaving the work and without breaking the arc. The change is very fast—the amperage can be changed from minimum to maximum or vice versa, within a few seconds. The operator can, on the other hand, make as little change, as slowly as the application demands. The amperage is controlled at the work by a reversible foot switch. This control is ideal for crater elimination and for amperage change by the operator when going from one thickness of metal to another. The heat can be reduced quickly or slowly at the option of the operator, thus eliminating the crater at the end of the weld. The control feature also enables the operator to start with a lower heat on thin gage material (eliminating the possibility of a burn through) and then increase the heat as desired. This procedure can be reversed on heavier material whereby the operator desires to start with a higher heat and then reduce the heat as the material heats up.

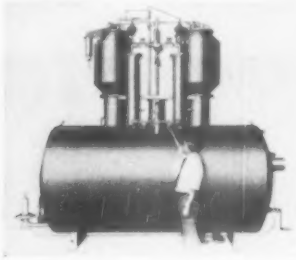
This is all accomplished, of course, without breaking the arc.

The welders are supplied in three amperage ranges—10 to 200 amp., 10 to 400 amp. and 10 to 700 amp.—in either "A" or "B" models. The "A" models have two foot switches. Power and high frequency are controlled by one switch and the amperage by the other. The gas and water are automatically controlled. The "B" models have only one foot switch for controlling the amperage. Power, high frequency, gas and water are automatically controlled. The touch method of starting is used.

Continuous Flow Acetylene Generator

To meet the needs of welding shops and industrial plants for large quantities of acetylene at minimum cost and maintenance, the Sight Feed Generator Co., West Alexandria, Ohio, has developed a new stationary type generator that produces a continuous flow of acetylene and is virtually automatic in its operation.

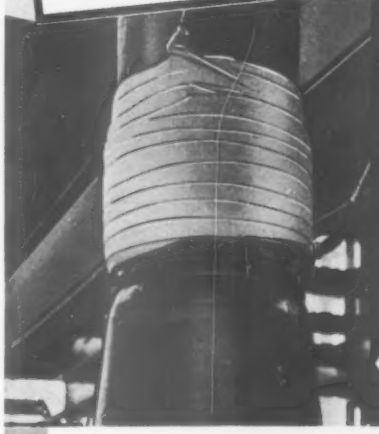
This latest addition to Sight Feed's line of portable and stationary generators will be known as the Model "A-Twin," so named from the two identical carbide hoppers atop the tank. The "A-Twin," like the Company's Model "A" single hopper unit, will use $\frac{1}{4} \times \frac{1}{12}$ calcium carbide in the production of acetylene.



The "A-Twin" requires a minimum of attention to keep it producing a continuous, uninterrupted flow of acetylene. Once the generator is placed into service, only two simple manual operations are needed: (1) Refill hopper with calcium carbide when empty; (2) Meter required amount of water into tank. Both jobs can be done simultaneously. To begin operation, both hoppers are filled with carbide. When the supply in one hopper is exhausted, the second hopper automatically goes into service. Shifting of the "load" from one hopper to the other is accomplished by setting the operating pressure of the number two hopper at one pound below the pressure of the number one hopper. After the first hopper has emptied its supply of carbide into the tank and the pressure drops one pound, the second hopper automatically begins to feed its charge of carbide. The first hopper can then be refilled and the cycle repeated.

Other outstanding features of the "A-Twin" include: (1) Safety; (2) A newly perfected dehydrator rubber throat at the

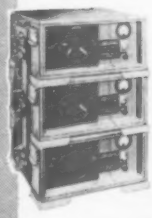
HOW WOULD YOU HEAT A HIGH PRESSURE WELDED PIPE JOINT TO 1700° F. 30 FEET UP IN THE AIR?



Do It With Smith-Dolan Preheating Stress Relieving and Normalizing Equipment-By-Induction-Heating at Low Frequencies.

Welded Joint in 20" O.D. — 1 3/8" Wall Carbon Moly Boiler Down-Comer Partially Wrapped for Stress Relieving.

- Smith-Dolan Heating Apparatus can be easily and safely handled by regular job personnel.
- It will deliver consistently perfect results under safe conditions assuring minimum job costs.
- Thorough heating of heavy wall metal sections can be achieved in a minimum of time with precise control.
- Proper heating is delivered according to set specifications and requirements of the Boiler and Piping codes.



NEW MODEL U-P — *Patented Smith-Dolan System, portable, low frequency induction heater, three-high stack (shown) 30 kva, 10 kva per unit. Buy one or stack two or three for increased capacity. Buy what you need; build as you go.*

AUTOMATIC CONTROL CABINET *used with Model U-P units (shown) and Model GC Duplex 120 or 150 kva induction heaters (shown in catalog).*

Electric Arc equipment can be rented or purchased for any job requiring preheating and stress relieving for welding and normalizing.

Write for Informative Catalog

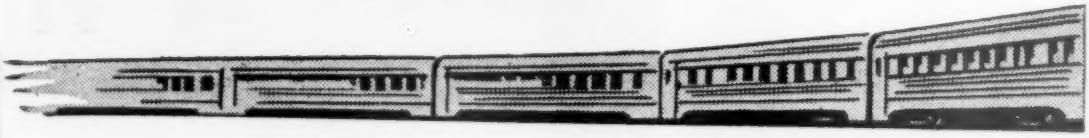
ELECTRIC-ARC INC.

ELECTRIC-ARC, INC.

161 JELLIFF AVE., NEWARK 8, N. J.

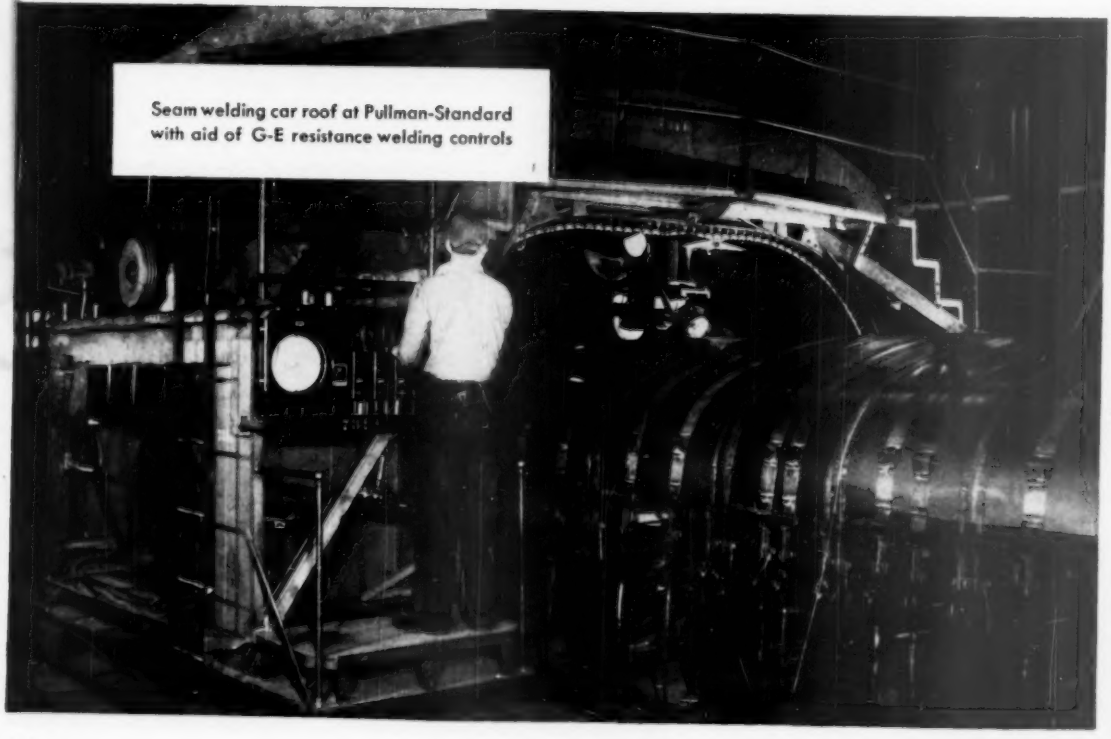
AC & DC Welding Equipment • Spot Welder Electrodes & Supplies

ELECTRONIC CONTROL FOR RESISTANCE WELDING

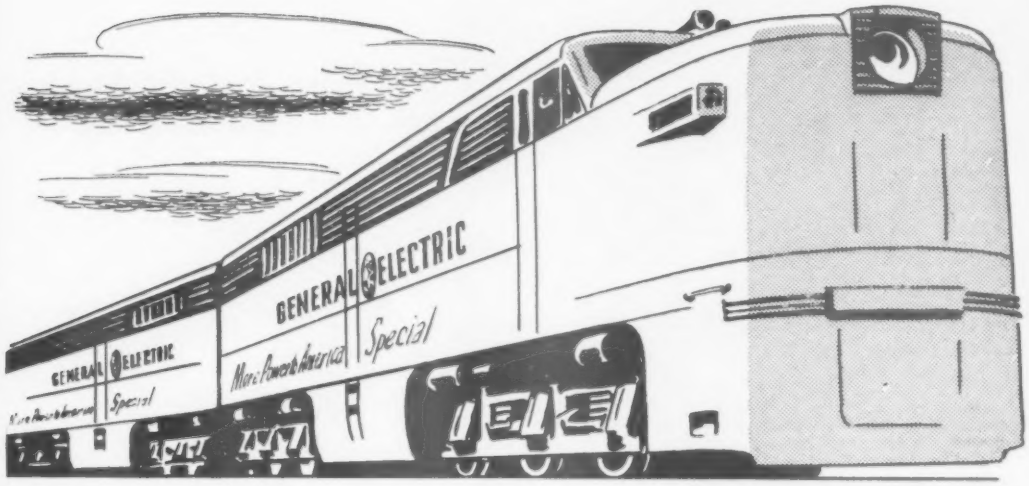


SPEEDED FABRICATION 100%

ON CARS FOR G-E



Seam welding car roof at Pullman-Standard with aid of G-E resistance welding controls



CUT REJECTS 75%

MORE POWER TO AMERICA TRAIN

Pullman-Standard Car Manufacturing Company, builder of the cars for the General Electric Apparatus Exhibit train now touring the country, has long been an enthusiastic user of resistance welding. This progressive company was one of the first to realize the savings in weight, increase in strength, and faster production that result from the use of this process. This company has also studied and capitalized on technical improvements over the years.

Completed car for G-E More Power to America exhibit train made for General Electric by Pullman-Standard.

It's CONTROL That Counts

Pullman-Standard has kept pace with progress in welding control. Today, Pullman-Standard uses modern G-E automatic electronic control which permits very close adjustment of heat and timing. Quality of welds is greatly improved. Compared with earliest control, the equipment now being used speeds fabrication on certain jobs 100%, cuts rejects 75%.

For Your CONTROL—Come to General Electric

Trained G-E engineers will be glad to discuss control problems with you and your resistance welding manufacturer, and from the wide variety of G-E control available can supply the right control for you.

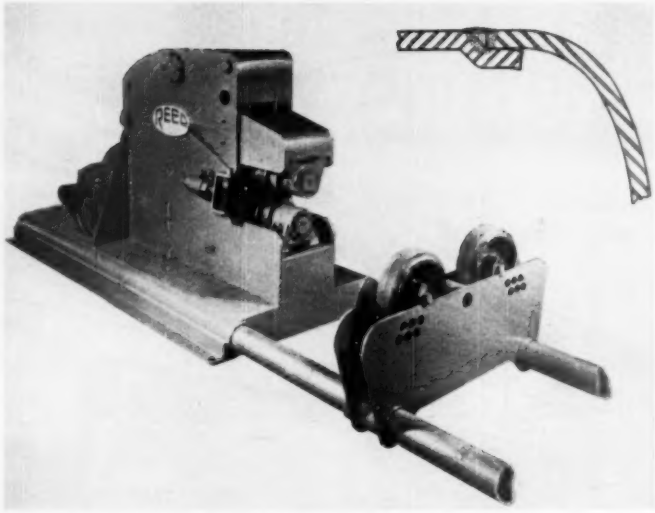
GENERAL ELECTRIC

base of each hopper that maintains dry atmosphere around the carbide feed valve, thus preventing clogging; (3) A flexing device that wipes the splash protector and dehydrator tube clean each time the carbide hopper is refilled; (4) An automatic water level control that permits the correct amount of residue to be discharged each time the tank is filled with water.

According to Sight Feed's catalog covering the new "A-Twin" Generator, the unit can be operated at any desired pressure up to 13 lb. per square inch. Since the "A-Twin" is a medium pressure generator, acetylene can be forced through long pipe lines without the use of compressors which would be required with low-pressure generators.

Offset Forming Machine

The Reed Engineering Co., 1003-17 W. Fairview Ave., Carthage, Mo., have recently developed a new Offset Process which represents the first new development in welded tank construction since the beginning of automatic welding. Circumferential seams on tanks and cylindrical shapes up to $^{7}/_{16}$ in. thickness can now be welded automatically without back-up bars or manual back-up welds. The general use of this offset joint has been approved by the A.S.M.E. Boiler Code. The Reed Offset Forming machine produces an offset at the ends of the shell section over which the tank heads or other shell sections can be fit for automatic welding, a typical welded joint detail of which

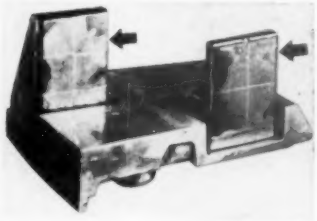


is shown above. The offset portion becomes the back-up eliminating the costly back-up bars. In the offset process the shell is made more nearly round and mill scale and rust are removed thus reducing fit-up and cleaning time. These factors all contribute to increased production rates at decreased production costs.

Illustrated above is the new Model M-4 Offset Forming Machine which is equipped with hardened steel-forming rolls. Hydraulic power is utilized for the offsetting pressure. The machine with standard forming rolls can handle material ranging from $^{3}/_{16}$ to $^{7}/_{16}$ in. in thickness. The minimum diameter which can be handled is 24 in. whereas the maximum diameter will depend upon the rigidity of the shell and material-handling equipment available. Approximate floor space requirements for the machine proper are 4 x 8 ft. Shipping weight is approximately 5000 lb.

Coal Pulverizer

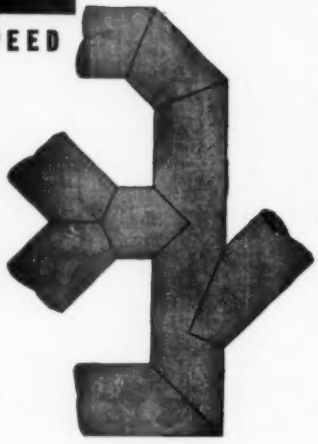
Sometimes it's the little things in life that count. The little pegs in a huge Riley coal pulverizer, for example, take terrific punishment as they reduce coal to talcum powder fineness. Until recently, cast pegs were used, and in one troublesome installation, these pegs were considered to have a satisfactory service life if they lasted through 3500 tons of coal. Then a suggestion was made to change to forged-steel pegs faced with carbide. A method of attaching the carbide facings to the forged pegs had to be developed. This was accomplished through the use of Easy-Flo No. 3 silver-brazing alloy in conjunction with a semiautomatic gas burner brazing setup having a capacity of 100 pegs per hour. Some of the redesigned pegs have now been in operation for months and show no appreciable wear after pulverizing upward of 30,000 tons of coal in contrast with the 3500 tons formerly handled.



CUTS
PRODUCTION AND MAINTENANCE COSTS MORE THAN HALF

SPEEDY LAYOUT JOBS ON PIPE AND STRUCTURAL STEEL

NOW! NEW EASE SPEED WITH THE CONTOUR MARKER



Compact, fits into hip pocket. Efficient, accurate, easy to use. Any of the angles in the illustration to the right can be marked off in five minutes or less on any pipe from 1½ to 18 inches. Save time, labor and gas—will pay for itself in one day.

IF YOUR LOCAL DISTRIBUTOR CANNOT SUPPLY YOU CAN ORDER DIRECT.

TO CONTOUR MARKER CORP.
1843 E. Compton Blvd.
Compton, Calif.

Please send me full details on the Contour Marker

NAME .....

COMPANY .....

STREET .....

CITY .....

Arc-Welding Electrode

A new improved arc-welding electrode, the W-2075, designed specifically for producing fully machinable welds on cast iron has been announced by General Electric's Apparatus Department.

The wetting action and ability to be used in all positions on either a.-c. or d.-c. current gives greater flexibility to the new W-2075 electrode. It is composed of pure nickel-core wire and an extruded black coating that is consumed in the arc giving a low volume of slag. The stable arc results in weld deposits that are color matching and of machine-like appearance, and offer increased resistance to cracking.

The new W-2075 is designed to operate at low currents, which minimizes brittle heat-affected zones in base materials.

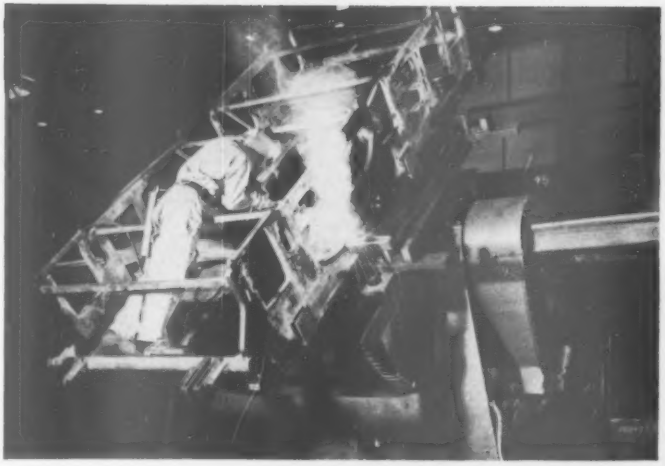
Range of sizes and the welding current required of the W-2075 electrode are from $^{3}/_{32}$ in. diameter, 50–70 amp. to $^{1}/_{16}$ in. diameter, 120–160 amp. All diameters are supplied in 14-in. lengths.

Acme Announces Special Gas Mask for Welders

To protect welders on jobs where there are hazardous gases or smokes due to product residue or vaporization, Acme Protection Equipment Co., Chicago, has developed a special full vision gas mask, to be known as Pur-a-weld, that can be used interchangeably with dust and fume canister or a compressed-air supply unit.

Advantages of this new type equipment, it is stated, include greater vision than ever before available in welding helmets; lenses in shades from 4 to 12; complete gas mask protection to reduce headaches, fatigue and other health hazards: easy fit and comfort; free-breathing; replaceable welding hood; interchangeable air supply to meet different conditions. The complete outfit is furnished in a compact carrying case.

Complete information can be obtained from Acme Protection Equipment Co., 3037 W. Lake St., Chicago 12, Ill.



More Arc-Time Per Hour

You pay your welders for welding . . . so the time it takes them to *position* the work—or themselves—is *lost* welding time.

But a Worthington-Ransome Positioner quickly tilts and rotates the work for practically *continuous* welding—always in the efficient *downhand* position that permits using heavier electrodes for *quicker, neater, better* welds.

Mass production or job welding . . . small pieces or "crane" work . . . automatic or manual welding—Worthington-Ransome Positioners quickly *pay* for themselves with increased production, lowered labor costs—up to 50%.

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Please send Bulletin 210C on Worthington-Ransome Welding Positioners.

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PERSONNEL

C. E. Monlux, New President of International Acetylene Association

Claude E. Monlux, Vice-President, The Linde Air Products Co., New York, N. Y., was elected President of the International Acetylene Association at the annual business meeting held during this organization's Annual Convention in San Francisco, Calif., March 27 to 29th. Mr. Monlux had served as Vice-President for the year 1949.

James W. Dunham, Vice-President, National Cylinder Gas Co., Chicago, was elected Vice-President of the Association. E. V. David, Assistant Manager of the Technical Sales Division, Air Reduction Sales Co., New York, was re-elected Treasurer. H. F. Reinhard was re-elected Secretary.

Federal Machine and Welder Representative

The Federal Machine and Welder Co., Warren, Ohio, has announced the appointment of the Austin-Hastings Co., Inc., as district representatives for the states of Maine, Vermont, Massachusetts, New Hampshire, Connecticut and Rhode Island.

The Austin-Hastings Co., Inc., who have a century of industrial experience, are located in Cambridge, Mass., with branch offices in Hartford, Conn., and Worcester, Mass. John Argento, Manager of the Welding Division, will operate from the Cambridge office, with able sales engineers working out of the other two offices.

Having a useful background of welding engineering from Northeastern University, as well as practical industrial experience in the welding field, Mr. Argento is in a favorable position to serve the needs of both old and new users of Federal resistance welders. He is a member of the AMERICAN WELDING SOCIETY.

Welding Machines Manufacturing Co. Officers

At the recent Annual Stockholders and Directors Meeting of the Welding Machines Manufacturing Co., Detroit, Mich., the following officers were elected for the ensuing year: H. V. Beronus, Sr., President; A. K. Jardine, Vice-President, and H. V. Beronus, Jr., Secretary and Treasurer. Mr. Beronus is a member of the AMERICAN WELDING SOCIETY.

OBITUARY

E. H. Ewertz

E. H. Ewertz, 76, who played a major role in the building of the first U. S. Navy submarine, died early April 7th while returning by train from Florida to his home in New London, Conn.

Mr. Ewertz, a consulting engineer for the Electric Boat Co. and past-president of the AMERICAN WELDING SOCIETY, was associated with John P. Holland in the building of the first successful Navy submersible.

He was an engineer at the Crescent shipyards in Elizabeth, N. J., when Mr. Holland brought in his first crude hull sketches in 1896. After the first submarine, the Holland, was accepted by the Navy in 1901, Mr. Ewertz supervised the building of six more submarines.

During World Wars I and II, he supervised the building of submarines and destroyers for the Electric Boat Co. He was a 50-year member of the Society of Naval Architects and Marine Engineers.

Mr. Ewertz was one of the pioneers in welding and active in the affairs of the AMERICAN WELDING SOCIETY. He served on many of its technical and standing committees as well as the Board of Directors. He wrote one of the first reports on the application of welding in ship construction. In recognition of his services he won the Samuel Wylie Memorial Medal and was made an Honorary Member of the SOCIETY.

Mr. Ewertz, who lived at 30 Farmington Ave., New London, is survived by his wife and four sons, Roy W., Harold N., Gorden Eric and Clement G. Ewertz.

design

MAKES ALL THE DIFFERENCE IN WELDING TEES, TOO

When seamless drawn welding tees were introduced some 17 years ago, they represented a great advance over cut-and-welded intersections. Even so, they still had certain inherent weaknesses. Their design was unstable under high internal pressure and bulging resulted at the flat spots of the side walls. The relatively weak crotch area, carrying an unequal share of the load, usually gave way first in bursting tests. To compensate, tees were made excessively heavy.

Tube Turns research engineers developed a new welding tee design based on the sphere, nature's strongest form for resistance to internal pressure. This shape, with necessary modifications, became the basis for an entirely new welding tee design.

In the Tube-Turn barrel-type tee, the internal pressure load is carried largely in direct tension. And, in bursting tests involving the old and new design, it proved capable of withstanding 22% more pressure before yielding. It is at least 25% stronger than the code (ASA B16.9) requires, as evidenced by these test results on 6" tees:

	BURSTING PRESSURE	
Schedule	ASA B16.9 Required	Test Minimum
40	4440 psi	5950 psi
80	6845 psi	8625 psi

Result of typical hydrostatic bursting test conducted in the Tube Turns research laboratory. The pipe itself split wide open under the terrific pressure applied; the new Tube-Turn welding tee is undamaged. Micrometer checks reveal no evidence of yielding or distortion.

FREE BOOKLET

Write for your free copy of "Research", a booklet reporting results of cyclic tests being conducted by Tube Turns engineers on the fatigue life of piping assemblies. Well illustrated. Contains valuable information on relative fatigue life of welding elbows, mitre bends, various types of flanges.

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SECTION ACTIVITIES

prepared by C. M. O'Leary

Anthony Wayne

The March Meeting of the Anthony Wayne Section was held on Friday, March 17th, in the Fort Wayne Chamber of Commerce building.

This meeting was a "Quiz the Experts" program. The following teams and personnel participated: Detroit Section represented by R. H. Bennewitz, The Linde Air Products Co., T. J. Crawford, Consulting Engineer; John Randall, Ford Motor Co.; and J. R. Stitt, R. C. Mahon Co. Indiana Section represented by J. R. Wirt, Delco Remy Division, General Motors Corp.; Carl Sauer, Reuas Engineering Co.; Ed Holt, P. R. Mallory & Co.; E. E. Goehringer, Lincoln Electric Co. Western Michigan Section represented by R. E. Kemp, American Seating Co.; E. Y. Bunting, Kilpatrick and Martin; D. Layman, Layman Welding Supply; C. Lankeneau, National Cylinder Gas Co. Anthony Wayne Section represented by B. G. Bishop, Lima Locomotive Works Division, Lima Hamilton Corp.; Carl L. Gaby, K & G Mfg. Co.; Virgil S. Beck, Beck Welding Co.; Geo. H. Laws, Ruckman & Hansen, Inc.

The Moderator was Prof. R. W. Lindley, head of the General Engineering Department of Purdue University. The Chief Judge was John Grodrian, Bendix Products Division, Bendix Aviation Corp., Fifth District Vice-President of the AMERICAN WELDING SOCIETY. Judges were Detroit Section, Al Last; Indiana Section, James F. Salatin; Western Michigan Section, Ivan R. Bartter and Anthony Wayne Section, Harry M. Johnson.

The teams, judges, moderator and committeemen met in the Round Table Room of the Chamber Building shortly after 3:00 P.M. The Judges, privately edited those questions submitted, worked out definite plans of conducting meeting and instructed the teams accordingly.

Dinner was served in the Auditorium at 6:30 P.M. musical entertainment was furnished from 7:30 to 8:00 P.M., and the Quiz Program started at 8:10 P.M. At the conclusion of the meeting team scores were added with the teams placing as follows: Indiana first with 349 points, Anthony Wayne second with 283, Detroit third with 263, and Western Michigan fourth with 250. All those participating received an automatic pencil from the Anthony Wayne Section as a token of their appreciation for the time and effort they had so graciously donated for the making of this meeting a success. Indiana the winners, received a trophy, an 8-man-hour job of a monstrosity portraying a new innovation for welding.

Arizona

The regular monthly meeting of the Arizona Section was held in the Aluminum Room of the Hotel Westward Ho on the evening of March 15th. It was a dinner meeting and there were approximately 35 people in attendance.

The speaker was Clinton Swift of the American Brass Co. of Waterbury, Conn., who spoke on the subject "Welding with Copper Alloys." Mr. Swift was very well qualified to talk on the subject as he has an excellent background which was proved by the thorough and interesting manner in which he discussed the composition and uses of the various copper alloys.

Following the talk an enthusiastic discussion took place in which Mr. Swift threw additional light on the problems of welding with copper alloys, after which the members of the Arizona Section thanked Mr. Swift for his fine talk.

Birmingham

The March dinner meeting of the 1949–50 season was held on the 9th at the Redmont Hotel, Birmingham, Alabama.

Speaker at the Technical session was D. C. Smith, Chief Metallurgist of the Electrode Division of Harnischfeger Corp., whose subject was "Low-Hydrogen Electrodes and Their Use in Industry." Mr. Smith presented a clear cut, interesting talk on the subject.

The April meeting was held on the 4th in Hooper's Cafe. This was a joint dinner meeting with the American Society for Metals. Approximately eighty members and guests heard Dr. Samuel L. Hoyt, Technical Advisor, Battelle Memorial Institute, Columbus, Ohio give an interesting talk on "Metallurgy of Welding." Included in Dr. Hoyt's talk was a detailed discussion of weldability tests and the effects of notch sensitivity on various types of steels.

A lively discussion followed the talk and the Section was fortunate to have a speaker of Dr. Hoyt's experience to answer the many questions from the audience.

Boston

The Boston Section held its March dinner meeting on the 13th at the Graduate House, M.I.T., Cambridge, Mass. Instead of a coffee speaker the Section had a very entertaining movie "Training of the Yankees."

Technical speaker was Robert C. Singleton, Manager of Customer Engineering, Nelson Stud Welding Division of Morgan Gregory Co. Subject "Stud Welding." Mr. Singleton first gave a very good account of the development of the Stud Welding process and then an interesting talk on its many uses in engineering. He also showed a film "Split Second Fastening" and slides illustrating unusual applications of Stud Welding.

Chicago

Leon C. Bibber, Welding Engineer of the Carnegie Illinois Steel Corp., was the guest speaker at the February 17th meeting. Mr. Bibber's illustrated talk dealt with the effects of general and local heating on the base metal, the effect of torch cutting and welding on shrinking and warping and the correction of warping and buckling.

Films on Football Highlights of 1949 and Daredevils on Ice were also shown.

There was an attendance of 110 at this meeting.

Cleveland

The regular April meeting of the Cleveland Section was held at the Allerton Hotel instead of the Cleveland Engineering Society. The meeting took place on Wednesday, April 12th. John M. Heffelfinger, Bridge Engineer for the City of Cleveland, presented an excellent paper on "Why Welding."

This paper was particularly timely and important because this was a joint meeting with the Cleveland Section of the Professional Engineers, the Iron League and the Cleveland Chapter of the A.S.C.E.

Mr. Heffelfinger, a graduate engineer from The Ohio State University, has been with the City of Cleveland for 51 years and has been extremely instrumental in the development of the new Cleveland Building Code, which incorporates welding.

G. W. Nichols gave a coffee talk on "Why the Farm Parity." Mr. Nichols discussed this highly controversial subject, both from the standpoint of the farmer, which he has been for many years, and also his chairmansip of the Government Production and Marketing Administration, successor to the A.A.A.

Colorado

The March 14th dinner meeting was held at the Silver Wing Inn, Denver, Colo. C. E. Adams, President of Adams Alloy Co., Wakita, Okla., presented an interesting talk on "Industrial Hard-Facing."

A film on the 1949 World Series was also shown.

Dallas

The February 22nd meeting was held in

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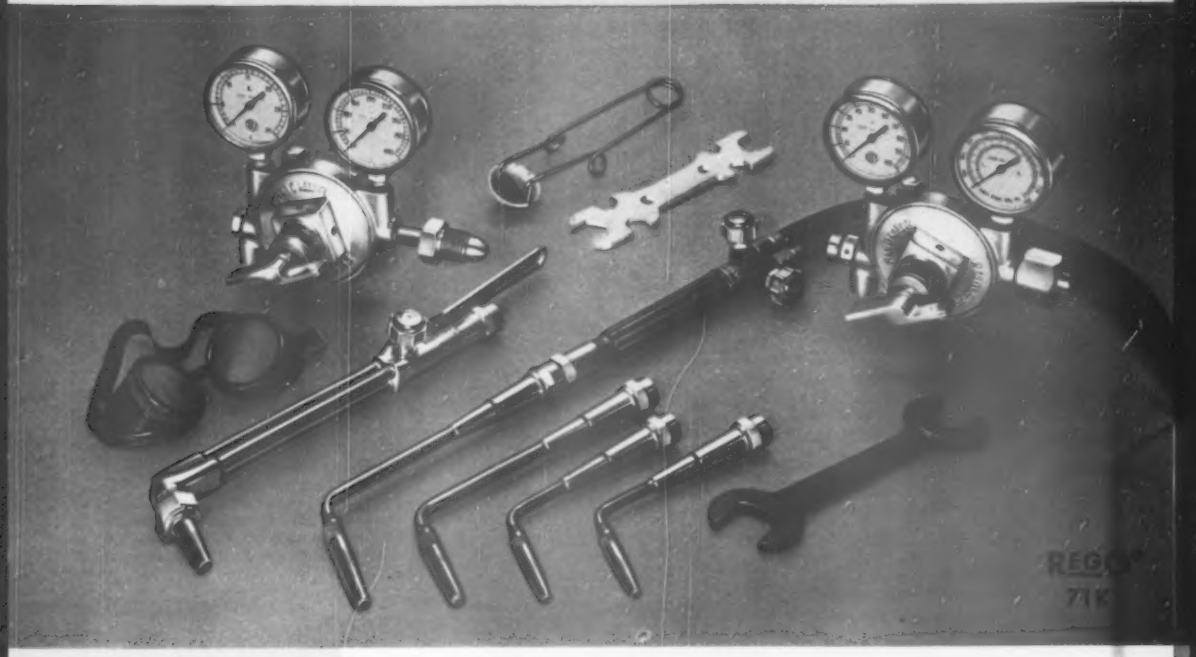

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With tips furnished, the 71K Outfit will weld from 16-gauge to ¾-inch thicknesses, and will cut up to 1½-inches. Additional tips available increase the welding range from 28-gauge to the heaviest sections, and the cutting range up to 6 inches. The KXA cutting attachment is supplied with a 75° head or 90° head as specified.

But the 71K is only one of many sturdy, efficient REGO Outfits to meet every welding and cutting need. Illustrated and described at left are two others, one for heavy-duty cutting, another for light welding. Send for catalog containing complete information on the wide variety of REGO welding and cutting apparatus ready to save you money and time.

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the Auditorium of the Lone Star Gas Co. Dinner at Earls Steak House preceded the meeting. Anthony K. Pandjiris' subject "Weldment Design and Application" was well received, and evoked interesting discussion.

The March 22nd meeting was also held in the Auditorium of the Lone Star Gas Co. Due to the inability of the scheduled speaker to be present, a color film was shown, and a question and answer program was conducted. The film was "Steel—Man's Servant."

Dayton

Raymond M. Dennis of the By-Products Steel Corp. of Coatesville, Pa., spoke to the Dayton Section on March 22nd on the topic "Machine Gas Cutting." Mr. Dennis, an authority on flame-cutting practice and steel plate shaping and fabrication, showed how the use of flame cutting has increased to the point where it is now considered as important a tool to the fabricator as welding itself. Through the use of slides, Mr. Dennis illustrated numerous examples of the type of mass production machine gas cutting done at By-Products Steel. Natural gas is used almost entirely to improve quality of cut. Special setups and special procedures were developed to increase production and quality and decrease distortion. Cutting plates 20 in. thick is not uncommon and often as many as 14 cutting torches are mounted on one machine. The use of the electric eye to follow templates not only gave more accurate work but also greatly reduced the cost of making templates. The presentation was followed by an interesting question and answer period.

Prior to the technical session, a sound color movie on the Arabian oil industry was shown. Plans were announced for the annual picnic to be held at the Frigidaire Gun Club on May 24th. Al Mealey was named picnic chairman. A social hour with refreshments concluded the program.

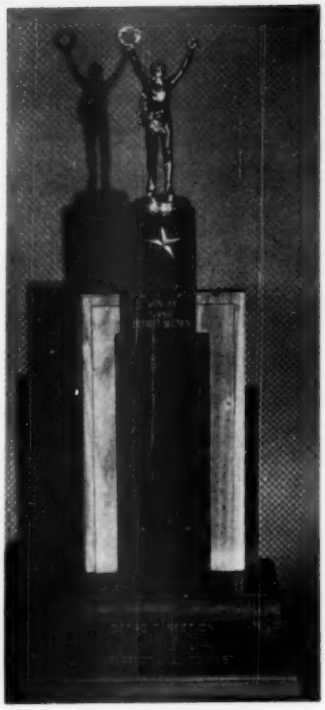
Detroit

The March 10, 1950, meeting of the Detroit Section started with a dinner meeting with 50 in attendance. Don De Groot, Public Relations Manager of WWJ and WWJ-TV, told of the problems facing the television advancement. His talk "What You Can Expect in Television" gave a better picture of the rapid advancement which has been made. He advised the audience that if they are waiting for colored television—they might wait five years. He stated that the trend is to larger and larger screens.

Roger J. Metzler, Development Engineer of Handy and Harman, told about the "Design for Silver Alloy Brazing." His talk was illustrated with a sound and color movie "Production Brazing with Low Temperature Silver Alloys." This showed actual brazing operations using flame, induction heating and controlled atmosphere furnaces.

The wide diversity of subjects presented this year is an achievement of which the Section program committee can well be proud.

Shown herewith is a photograph of the



Detroit Wins Trophy

trophy awarded the Detroit Section at its March meeting for winning the Inter-sectional competition at the Quiz the Experts program in February.

The program has been an annual event of the Detroit Section which invites three other Sections to compete. Questions are sent in by the Detroit membership on practical problems which they have encountered. The program usually creates a lot of interest, and lively discussion by the competing teams is enjoyed by the membership.

This year the trophy was donated by Walter Anderson of Denton and Anderson who represent Taylor Winfield.

It is planned to continue the annual event, and to inscribe the name of the winning Section and the year on the trophy.

Teams from Detroit, Niagara Frontier, Anthony Wayne and Indiana Sections competed in this year's event held on February 10th.

Hartford

The March 9th dinner meeting was held at the Rockledge Country Club, West Hartford, Conn. Technical speaker was F. E. Garriott, Product Manager, Ampco Metal, Inc. His subject was "Welding with Bronze Electrodes."

Following the meeting, group singing, with R. S. Studzinski, Accordionist, was enjoyed by those who remained. It was a typical barbershop quartet setup.

Indiana

The March 24th meeting was held in the Indianapolis Plant of the R.C.A. Corp. with a total attendance of 174. Among the many guests in attendance were representatives from the Richmond, Dayton and Fort Wayne Sections.

Dinner was served in the R.C.A. cafeteria followed by a tour through two departments, one of which manufactures standard electronic vacuum tubes, and the other miniature tubes. Both tubes were of the type used in most radios. Of particular interest were the special equipment and processes used to make the entire tube assembly, as well as the female operators. Of course, the only interest in the latter was in their skill at their particular operation.

The speaker was introduced by George Reiling, R.C.A. District Service Engineer for Industrial Electronic Tubes. H. H. Wittenberg, of the R.C.A. Lancaster Engineering Department, spoke on "Testing Gas Filled Industrial Electronic Tubes to Predetermine Failure." This subject was covered complete with circuit diagrams. The subject covered is to be put out by R.C.A. on Engineering Data Sheets.

It was announced by the Chairman that the Quiz Team had won another trophy at the March meeting of the Ft. Wayne Section.

Kansas City

The Kansas City Section held its March dinner meeting on the 16th at Fred Harvey's, Union Station.

C. E. Adams' talk on "Industrial Hard Facing" was particularly informative in the agricultural field.

Following the technical session a film on Jungle Animal Life and Sports was shown.

Lehigh Valley

E. C. Korton, Assistant Chief Engineer, Boiler Division, Hartford Steam Boiler Inspection and Insurance Co., was the guest speaker at the monthly meeting held on April 3rd at the Hotel Bethlehem, Bethlehem, Pa. A. E. Charlesworth, Section Chairman, presided.

Mr. Korton gave an illustrated talk on "Boiler Codes." He gave a very interesting discussion on the need for codes, describing numerous failures which lead to investigations to determine methods of fabricating and testing boilers. Mr. Korten explained the various tests which are necessary to qualify both the procedure and the welding operator for boiler code work. Members and guests participated in a discussion period following Mr. Korten's presentation.

A dinner meeting was held prior to the technical session.

Fifty members and guests made an afternoon plant tour of the Bethlehem Steel Co., Bethlehem, Pa. The tour included a visit to the blast furnaces, open hearths, rolling mills, fabricating shops and weldment shop. Following the trip through the Plant, the group was shown a very interesting and educational sound film entitled, "How Steel Is Made."

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Both the "140" and "130X" electrodes are used for welding Monel®, but each of these rods is designed to do a specific job.

For best results... sound, strong, corrosion-resistant welds... it pays to make sure you have the right rod for the job at hand.

Check the following table carefully when in doubt ...and file it for future reference!

QUESTION	• "140" ELECTRODE	• "130X" ELECTRODE
1 Which rod is right for welding solid Monel in all positions?	May be used if no "130X" is at hand.	Best
2 Which rod for overlaying Monel directly on steel?	Yes	No. A barrier layer of nickel must first be laid down.
3 Which for joining wrought or cast Monel to steel or stainless steel?	Yes	No
4 Making direct Monel-to-steel welds?	Yes	No
5 Joining Monel to nickel?	Yes	Best
6 What are the recommended amperages?	3/32" 35-60 amp. 1/8 " 70-110 amp. 5/32" 110-150 amp. 3/16" 140-190 amp.	.075 " 25-40 amp. 3/32" 45-60 amp. 1/8 " 60-95 amp. 5/32" 80-150 amp. 3/16" 140-190 amp. 1/4 " 170-260 amp.
7 What type of current and polarity must be used?	D.C. Reversed polarity.	D.C. Reversed polarity.
8 Are the corrosion-resisting properties of the weld deposit comparable to those of the parent metal?	Yes	Yes
9 Do the mechanical properties of the weld deposit compare with those of the parent metal?	Yes, assuming parent metal is in the soft-temper condition.	Yes, assuming parent metal is in the soft-temper condition.

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Louisville

J. D. Mattimore, Chief Engineer, Product Engineering and Research Department, Tube Turns, Inc., Louisville, Ky. was the guest speaker on March 28th. He gave a talk profusely illustrated with lantern slides on the subject "The Effect of Welding on Piping Design and Construction."

Mr. Mattimore's talk traced the various methods for joining pipe for industrial installations and he showed how through the many developments in the welding processes, advances and improvements have been made in the layout and construction of piping systems.

After the discussion period, the movie "The Evolution of the Oil Industry" was shown and the evening closed with a social hour and lunch.

Maryland

The March meeting of the Maryland Section was held at the Engineers' Club on the 17th with a dinner attendance of 41, which enjoyed a talk by U. W. Richardson on "Rocket Propelled Pilotless Aircraft." The interest of the audience was engaged not only by the performance features which were illustrated by a film furnished by the Glenn L. Martin Co., but also by the fact that welding plays a very important part in the construction of this type aircraft which exemplifies the latest advances in aeronautical engineering. A small exhibit showed typical examples of welding in modern aircraft. The technical speaker of the evening, J. Maniulli of the Titan Metal Mfg. Co., Bellefonte, Pa., presented a paper on "Brass Welding" before 86 members and guests. A colored film illustrated the talk which concerned itself mainly with the practical aspects of manufacturing and application of brass welding rods. A small exhibit of principal types of welding rod aided in visualizing the subject matter.

Michiana

For their March excursion into the realm of technical learning, members of the Michiana Section witnessed a demonstration of Tool and Die Welding by Frank E. Kessler, Engineer, Welding Equipment and Supply Co., Detroit, Mich. Approximately 40 members and guests gathered at the Wheeler and Hamilton Welding Shop, and saw two slide films, "Let's Get the Low-Down" and "Let's Do It Right" to get some of the theory behind tool and die repair, and then stayed to watch Mr. Kessler actually make deposits of some of the tool electrodes and rods. Both arc and acetylene welding were demonstrated.

Members were shown how to put a new tooth on a milling cutter, to replace the point on a turning tool and to build up a blanking die. The versatility of this method of saving money for the metalworking industry was made very apparent.

Milwaukee

Over 50 members attended the buffet dinner preceding the March 24th meeting. Following the dinner the members and guests were entertained by a delightfully humorous yet impressive story of the rise of an immigrant molder, P. Kreulen, to vice-president of a large foundry system. It was an inspiring talk sprinkled with anecdotes and laughs.

The technical speaker was S. V. Williams of the A. O. Smith Co. who discussed the importance of engineering and preliminary planning of production welding for profit. Mr. Williams pointed out that there must be close cooperation of all concerned from the shop through the engineering, inspection and purchasing departments if the best weldments are to be produced at a minimum cost.

New Jersey

The March 21st meeting was held in the Essex House with approximately 35 attending dinner and 75 attending the Technical Session. The film "Alloy Steels" was shown prior to the meeting.

John A. Randall, Welding Engineer of the Ford Motor Co., talked on Welding in the Automobile Industry. The prodigious volumes of 40 million spot welds on bodies and 36 miles of arc welding on frames per 24-hr. period are illustrative of the high production rates required. In order to realize high production at low cost, the selection of process is based upon the following factors: Production rates; maintenance requirements and reliability; Minimum Operator skill; Minimum operator labor; Minimum floor space; Adaptability to straight line flow; Ease of modification.

Resistance welding, particularly spot, seam and projection best fit these requirements.

Mr. Randall gave an excellent talk. He asked for questions from the floor and he was flooded with them at times, but he was always in command of the situation.

The after dinner snack offered an opportunity for all to get together.

New York

At a joint gathering on March 15th of the members of the New York Section of the AMERICAN WELDING SOCIETY and the Metropolitan Section of the American Society of Civil Engineers, George Dunkelberger, Architect, Connecticut Highway Department, spoke on the subject "Welding Design and Practice for Highway Bridges."

Mr. Dunkelberger spoke of the great advances in highway construction in the last 30 yr., pointing out that in 1919 the major traffic arteries in the State were no wider than about 18 ft., or 28 ft. including the shoulders. In contrast to this he pointed to the splendid highway system linking all parts of Connecticut today, as exemplified by the Merritt Parkway and Wilbur Cross Parkway recently completed. Mr. Dunkelberger called attention to the fact that the State Highway Department of Connecticut had pioneered in the use of welded structures for the bridges spanning these highways whenever possible. For example, of 36 bridges on the Merritt Parkway, 30 of them are of welded construction. He brought out the fact that they had found welded construction to be more economical, principally in the saving of steel that results from designing for welding.

Mr. Dunkelberger's paper was commented upon by C. L. Kreidler, Chief Structural Engineer of The Lehigh Structural Steel Co., who dwelt on the subject of welded bridges from the viewpoint of the fabricating shop. Mr. Kreidler reported many of the details of the welding on several of the bridges covered in the principal speaker's paper. He confirmed that welded construction proved to be less costly, chiefly in the saving of steel tonnage, but also he stated that there was a saving to be realized in field erection costs when welded design had been employed.

The meeting was conducted by Charles Molineaux, President, Metropolitan Section, American Society of Civil Engineers, who also served as Technical Chairman. It was held in the Engineering Societies Building.

Niagara Frontier

Quiz Night was held on March 23rd at the Sheraton Hotel, Buffalo, N. Y. with Toronto and Rochester Experts vs. Niagara Frontier Experts. Chairman C. H. Jennings was assisted by C. E. Jackson. The Quiz lasted for 2 hr. and 10 min. Toronto Section took the prize with the other two Sections ending in a tie and only 2 points behind. Olean Division did not appear as planned, due to bad weather. Approximately 85 were present.

A Buffet Supper Dance is planned for the 20th annual installation meeting late in May.

Northwest

Speaker for the February 13th meeting was to have been Lew Gilbert, Editor of *Industry and Welding*. However, a death in the family prevented his appearance. A question and answer substitution was hurriedly assembled and a most successful meeting was conducted by men from the Section. Guided by C. M. Clogston, a panel of four men included Buck Hixson, Ed Hall, A. P. Demmer and Dick Simmons.

Marquette Mfg. Co., Inc., was host at the "Happy Half Hour" preceding dinner.

The March meeting was held on Monday, March 13th, at the Covered Wagon in Minneapolis.

C. B. Voldrich, Chief Welding Engineer, Battelle Memorial Institute, Columbus, Ohio addressed the Section on "Weldability of Steels."

Mr. Voldrich's discussion was most ably delivered and proved to be one of the most interesting of the year. Slides illustrated the lecture and were followed by a question and answer session.

Air Reduction Sales Co. was host for the half hour preceding dinner.

Oklahoma City

Anthony K. Pandjiris, President of the Pandjiris Weldment Co., was the guest speaker at the February 21st meeting held in the Biltmore Hotel. Mr. Pandjiris'

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... ***BUT*** they've been "given the works" by many large fabricators of stainless steel equipment—on the job. And, from all reports, they're the most all 'round satisfactory electrodes PAGE ever developed for any kind of weld on any type of stainless steel. And PAGE has been making stainless steel electrodes since the early development of stainless.

Ask your Page distributor about these new, improved Stainless Steel Electrodes

ACCO

Monessen, Pa., Atlanta, Chicago, Denver, Detroit, Los Angeles, New York, Philadelphia, Pittsburgh, Portland, San Francisco, Bridgeport, Conn.

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PAGE STEEL AND WIRE DIVISION
AMERICAN CHAIN & CABLE

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2 New

Automatic "Hot-start" Control for Instant Arc Striking

*

G-E Silicone Insulation for Compactness,

New Model 6WK20H 200-amp a-c welder

200-AMP MODEL — $180†

Weighs 154 lbs.

This little welder gives you more welding amps per pound—and more value for your welding dollar than any other standard a-c welder available today. And it's still a hard-working industrial welder with a current range from 30 to 250 amps, ($\frac{1}{16}$"—$\frac{3}{16}$" electrodes) 30 volts, and 50% rated duty cycle.

23" high, 12" wide, and 17" deep, it's easily carried about, or tucked away in spaces too small for bulkier units. Its fully automatic "hot-start" gives instant arc striking on any current setting with no manual adjustment needed. Maintenance is easy and inexpensive, and you can weld many a job without having to tie up large units. Write your distributor for bulletin GEC-553.

†List price for zone 1 (eastern); prices slightly higher in zones 2, 3, 4.

GENERAL ELECTRIC

711-13

ALABAMA—Young & Vann Supply Co. Box 2532, Birmingham; Turner Supply Co. Box 1429, Mobile
ARIZONA—Arizona Welding Equipment Co. 230 S. Central, Phoenix
CALIFORNIA—Victor Equipment Co. 844 Folsom, San Francisco
COLORADO—Hendrie & Bolthoff Co. 1635 17th St. Denver (also WYO.)
FLORIDA—Cameron & Barkley Co. 605 E. Forsyth, Jacksonville
GEORGIA—Welding Supply & Service Co. 295 Techwood Dr. NW, Atlanta; Georgia Oxygen Co. Box 1077, Macon
IDAHO—Olson Manufacturing Co. 4000 Warm Springs Ave., Boise
ILLINOIS—Machinery & Welder Corp. 1324 W. Fulton, Chicago (also IOWA)
INDIANA—Drill Master Supply Co. 1305 First Ave. Evansville; Sutton-Garten Co. 401 W. Vermont, Indianapolis, Perry Welding Sales & Service, 424 E. Monroe, South Bend
KANSAS—Watkins, Inc. 204 N. Waco, Wichita
KENTUCKY—G-E Supply Corp., Haskins St., Harlan; Mine Service Co., Lothair; Reliable Welding Co. 630 S. 15th, Louisville, Big Sandy Electric & Supply Co., Pikeville
LOUISIANA—Equitable Equipment Co. 410 Camp, New Orleans; Hughes Welding Supply Co. 413 Fortson, Shreveport
MARYLAND—Arcway Equipment Co. 920 E. Fort Ave. Baltimore (also DEL.)
MASSACHUSETTS—General Electric Welding Sales, 9 Putnam St., Fitchburg (also MAINE, VERMONT, NEW HAMPSHIRE); Welding Engineering Sales Corp. 150 Causeway, Boston

a-c welders

Long Life, Light Weight

New Model 6WK30J 300-amp a-c welder

300-AMP MODEL — $310†

35" high; weighs 325 lbs.

For heavier-duty applications, this model handles $\frac{3}{32}$" to $\frac{1}{4}$" electrodes (current range 40 to 375 amps), is rated at 40 volts with a 60% duty cycle. Only 19" in diameter, it's really a miser on floor space.

Excellent arc-striking characteristics (automatic "hot-start," of course) and elimination of popouts means faster welding, sounder welds, and lower operating costs. Its job range, running from light-duty, low-current sheet metal jobs to heavy-duty, high-current applications, make it an excellent all-around, general-purpose welder.

Ask your distributor for bulletin GEC-652. *Apparatus Department, General Electric Company, Schenectady 5, N. Y.*

* *New, water-repellent, temperature-resisting, insulating material means increased operating dependability.*

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MICHIGAN—Welding Sales & Engineering Co. 8750 Grinnell Ave. Detroit; Miller Welding Supply Co. 505 Fulton, Grand Rapids
MINNESOTA—Machinery & Welder Corp. 2440 2nd St. Minneapolis; W. P. & R. S. Mars Co. 324 W. Michigan, Duluth
MISSISSIPPI—Jackson Welding & Supply Co. 145 E. South St. Jackson
MISSOURI—Machinery & Welder Corp. 700 S. Spring, St. Louis (also IOWA); Hohenschild Welders Supply Co. 512 E. 18th, Kansas City (also KAN.)
MONTANA—Montana Hardware Co., 823 S. Montana, Butte
NEBRASKA—Lincoln Welding & Supply Co. 330 S. 10th, Lincoln; Baum Iron Co. 13th & Harney, Omaha (also IOWA)
NEW JERSEY (Northern)—Welding Engineering Sales Corp. 40 Goble St., Newark
NEW MEXICO—Industrial Supply Co. 1647 N. 2nd St. Albuquerque; Bowen Welding Supply, 1320 W. 7th, Clovis; Western Oxygen, Inc. 207 W. Dunham, Hobbs; Car Parts Depot, 302 N. Main, Las Cruces
NEW YORK—Welding Engineering Sales Corp. 110 E. 42nd, New York (also CONNECTICUT)
NORTH DAKOTA—Dakota Electric Supply Co. 1017-23 Fourth Ave. N., Fargo
OHIO—Burdett Oxygen Co. 3300 Lakeside, Cleveland; Menna Welding Co. 1102 West Central, Toledo
OKLAHOMA—General Electric Welding Div. 915 E. 2nd St. Tulsa
OREGON—J. E. Haseltine Co. 115 S. W. 2nd Ave. Portland
PENNSYLVANIA—Arcway Equipment Co. 49th & Grays Ave. Philadelphia (also Southern N. J.); 5118 Penn Ave., Pittsburgh
SOUTH CAROLINA—Cameron & Barkley Co. Box 906, Charleston; Welding Gas Products Co., 407 Fall, Greenville
SOUTH DAKOTA—Hendrie & Bolthoff Co. 629 Main, Deadwood
TENNESSEE—Welding Gas Products Co. Box 749, Chattanooga; Delta Oxygen Co. 611 Court, Memphis (also ARK.)
TEXAS—M & M Welding Supply Co. 1818 Butternut, Abilene; J. Ernest Stroud Co. 501 E. Third, Amarillo; Briggs-Weaver Machinery Co. 5000 Hines Blvd. Dallas; Dallas Welding Supply Co., 430 S. Industrial Blvd., Dallas; Car Parts Depot, Inc. 712 Texas, El Paso; Welding Equipment Co. 1413 E. Lancaster, Ft. Worth; Acetylene & Oxygen Co., Harlingen; General Electric Welding Div. 5931 Clinton Drive, Houston; West Texas Oxygen Co. 2607 Ave. "M," Lubbock; Western Oxygen, Inc. 2700 W. 2nd, Odessa; Plains Welding Supply Co. 221 E. 6th, Plainview; Southwestern Welding Supply Co. 65 East Ave. San Angelo; San Antonio Machine & Supply Co. Drawer 660, San Antonio; Hughes Welding Supply Co. 2007 W. 7th, Texarkana (also ARK.)
UTAH—The Galigher Co. 545 W. 8th South, Salt Lake City
VIRGINIA—Arcway Equipment Co., 5931 Madison, Newport News
WASHINGTON—J. E. Haseltine Co., 510 First Ave. S. Seattle
WEST VIRGINIA—Bluefield Supply Co., Bluefield; Virginian Electric Inc. 57 Michigan, Charleston; Logan Hardware & Supply Co., Logan
WISCONSIN—Machinery & Welder Corp., 3623 W. National Ave. Milwaukee
ALASKA—Northern Supply Co., Anchorage
HAWAII—W. A. Ramsey, Ltd. Box 1721, Honolulu
CANADA—Canadian General Electric Co., Toronto
OTHER FOREIGN COUNTRIES—International General Electric Co.

subject was on Weldment Design as it relates to the over-all problem of producing economical weldments. Mr. Pandjiris is an authority on Weldment Design and Engineering Practices.

Philadelphia

The long heralded "Battle of the Sections" featuring participants from the Washington, Maryland, Lehigh and Philadelphia Sections held on March 20th was an outstanding success.

The team from the Baltimore Section consisting of G. E. Claussen, Reid Avery Co., J. C. Cumberland, Areway Equipment Co., and Fritz Albrecht won the honors for the evening, with each member of the team receiving an engraved cigarette lighter as a memento of the meeting.

A. J. Raymo of the Baldwin Locomotive Works, as moderator for the contest, kept the teams on their toes by opening the answers of the participants to question and discussion from the audience.

The knowledge and ability of the winning team was fully extended by the Washington Section team with T. J. Griffin, Bureau of Ships, Navy Department, H. L. Ingraham, Air Reduction Sales Co. and W. E. McKenzie, Washington Gun Factory, Navy Department. The Lehigh Section team consisted of H. O. Hill, L. P. Elly and R. E. Somers, all of the Bethlehem Steel Co.; and the Philadelphia Section team with H. W. Pierce, New York Shipbuilding Corp., J. S. Douglass, The Linde Air Products Co. and Walter Mehl, Heintz Mfg. Co.

The Judges for the contest were A. G. Bissell, U. S. Navy, from the Washington Section, E. B. Lutes, Arcrods Corp., from the Maryland Section and E. L. Durkee, Bethlehem Steel Corp., from the Lehigh Section.

The varied questions and their answers by the high caliber men on each of the teams with a critical audience to qualify their answers, made the "Battle of the Sections" most interesting as well as informative.

The reception and response to the meeting would indicate that more inter-Sectional activities might well be in order.

A Dinner Dance will be held on Saturday, May 13th at the Engineers Club, Philadelphia.

Pittsburgh

Regular monthly meeting was held on March 15th at Mellon Institute, Pittsburgh, Pa. Dinner preceded the meeting at Hotel Webster Hall. C. H. Jennings, Second Vice-President of the AMERICAN WELDING SOCIETY was the dinner speaker. Mr. Jennings talked on the general condition of the Society, financial and membership drive and the work of the Sections.

Technical speaker was W. B. Bunn, Senior Welding Engineer, M. W. Kellogg Co., Jersey City, N. J., whose subject was "Inspection of Welding." A film was shown in conjunction with the paper on the fabrication and erection of the San Francisco Bridge.

In the absence of Chairman T. W. Morgan, Vice-Chairman E. H. Turnock officiated as Chairman of the meeting, which had an attendance of 123.

Rochester

The members of the Rochester Section who attended the March 20th dinner meeting held at Guy Michael's Restaurant all have spring fishing fever since seeing the movies, "Fresh Water Fishing, Salmon and Rainbow Trout Fishing," shown at this meeting.

Technical lecture was presented by Henry H. Brown, Chief Metallurgist of Eastman Kodak Co. Mr. Brown's subject was "Practical Applications of Welding Metallurgy." He dealt with stainless steel fabrication. By use of slides he showed some excellent examples of improper application of materials, weld joints and penetration; corrosion in the heat-affected zone due to carbide precipitation, and stress corrosion failures. He pointed out the cause and solution of these failures by aid of X-rays and photomicrographs of practical applications. Mr. Brown stressed the importance of coordinating design, metallurgy and procedure to maintain and improve the reputation that welded fabrication justly deserves. A very interesting discussion followed.

In a truly pioneer spirit representatives Joe O'Rorke, Bob Cattanach, Bill Douglas, Walt Dick and Ed Habel set out for the Western Frontier in the teeth of the first spring blizzard. Ed Habel acted as a judge in the "Battle of the Sections" which was won by a team from Toronto. Rochester and Buffalo tied for second place. Everyone had a grand time and expressed their appreciation of the hospitality extended by their friends in Buffalo.

Saginaw Valley

The Saginaw Valley Section held its February meeting on the 9th in Flint, Mich. This meeting was in the form of a plant visit to Chevrolet—Flint Mfg. Division of General Motors. Three hundred and fifteen people attended. Geofrey Burrows, Welding Engineer, answered questions after the tour which featured the welding and brazing of the new power glide transmission developed by Chevrolet. Samples of welded parts including those of the power glide were on display when the tour ended and questions were answered.

The March 9th meeting was held at The Chanticleer, Saginaw, Mich. Ray Ladd, Chairman, gave a status of the membership drive and members of the Austin Co. present were introduced by James Jenkins.

Technical speaker was Roger J. Metzler, who spoke on Design for Silver Alloy Brazing. A film was shown in conjunction with the paper on Production Brazing with Low Temperature Silver Alloys.

San Francisco

Regular monthly dinner meeting of the San Francisco Section was held on March 27th at the Engineers' Club.

Technical speaker was Clinton E. Swift, Sales Engineer of The American Brass Co. Mr. Swift's illustrated talk was on Welding with Copper Alloys.

A new sound film produced by The American Brass Co. was previewed at this meeting and very well received. Its title was "Oxyacetylene Welding and Cutting."

Susquehanna Valley

The March 8th dinner meeting was held at the Hotel Berwick, Berwick, Pa. An ACF-TALGO Movie was shown after dinner and very well received.

Technical speaker was George Kiefer, Associate Director of Research, Allegheny-Ludlum Steel Corp., whose subject was "Welding of Stainless Steels."

The first year of this new Section was brought to a very successful end at its business and technical session on Wednesday, April 5th, held at Lewisburg, Pa.

A tour of Bucknell University Engineering facilities and the new college power house preceded the technical session. This tour was very well conducted by students in attendance at each Lab. to give full details of units on display. Students were under the direction of Prof. J. B. Miller.

An illustrated talk was given by E. C. Korten, Hartford Steam Boiler Inspection and Insurance Co., on Boiler Codes. Slide from the Hartford files showing boiler explosion damage were shown. Informal discussion of varied industrial problems followed.

The election of officers for 1950–51 were announced as follows: C. H. Folmsbee, *Chairman*, Bloomsburg, Pa.; C. E. Reedy, *Vice-Chairman*, W. Milton, Pa.: D. B. Howard, *Secretary*, Berwick, Pa.; O. H. Philips, *Director*, Berwick, Pa.; S. E. Bunn *Director*, Luzerne, Pa. and R. C. Bellas, *Treasurer*, Milton, Pa.

These officers will take office after the May meeting.

The final spring meeting will be held on May 24th and will be in the form of an annual ladies night. This meeting will be held at Irem Temple Country Club, Dallas Pa., just a few miles north of Wilkes-Barre, Pa. The couples desiring a good day of fun will arrive after lunch to begin a golf tourney at 2 P.M. (cards for others) and a dance after the evening banquet.

Tri State

The March 30th dinner meeting was held at Beckelman's, Evansville, Ind. Speaker was Mr. Rogerson, who was assisted by Mr. Smith, in presenting the subject, "Aluminum Joinings." A film and slides illustrated the address. This was very interesting, showing how aluminum was made and formed from bars into structural steel and all the way down to candy wrappers.

Washington, D. C.

The regular monthly dinner meeting was held on Tuesday, March 28th at Club 400. Coffee speaker was S. Herbert Evison, Chief Information, National Park Service, Department of the Interior, whose very interesting talk on the National Parks was very well received.

Technical speaker was Robert H. Pool, Electrical Superintendent, Truscon Steel Co., whose subject "Prefabrication of Steel

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Homes and Mill Buildings" was also very well received.

Refreshments were served following the meeting.

Western Massachusetts

On March 14th the Western Massachusetts Section met at Blake's Restaurant in Springfield. The technical speaker was Jim Craig of The Linde Air Products Co. who spoke on powder cutting as a production tool. Mr. Craig stated that powder cutting consists essentially of the introduction of an iron-rich powder into an oxygen-rich acetylene flame. The iron powder burns forming super-heated iron oxide slag which melts the steel and washes away the iron oxides. Powder cutting is particularly adaptable to use with stainless steels and similar corrosion resistant ferrous metals.

As an example of cutting speeds and thicknesses, figures were given for the cutting of type 316 stainless steel. A 16-in. slab was cut at speeds up to 12 in. per minute, but this requires a preheat of 1800° F. It was also reported that casting risers as thick as 44 in. have been cut successfully.

Mr. Craig's talk was followed by a short, but interesting, question and answer period.

Wichita

An informal plant visit was made to the Forster Mfg. Co. Plant on March 13th, followed by a buffet supper at the Plant, both of which were enjoyed by all. A short business session took place before the technical session.

Speaker at the technical session was C. E. Adams, President, Adams Alloy Co., Wakita, Okla. Mr. Adams' subject was on Hard Facing Alloys. A live demonstration of hard facing on plow shares and small parts followed. Considerable interest was shown.

Worcester

On March 29th a joint meeting was held between the Worcester Section of the A.W.S. and the Worcester Society of Civil Engineers. One hundred and thirty-five members and guests attended and the speaker of the evening was C. S. Kreidler, Chief Structural Engineer of the Lehigh Structural Steel Co., Allentown, Pa., who presented a paper on "Structural Welding."

Mr. Kreidler described the shop and field welding of structural steel used in connection with the erection of the new thirteen story building for the Jordan-Marsh Co. department store located in Boston, Mass. The structure is being built in two phases. The first phase, five units, seven stories high, is to be constructed in sequence to cover the entire site. The second phase will add the upper stories. The first unit is now in operation. There are 2500 tons of steel in this unit. Shop connections were welded except for the heavy girder joint over the subway entrance which was shop riveted. Field connections to columns or struts, girders to girders, beam carrying struts, elevator and stair framing and sealed beam to beam connections are welded. Mr. Kreidler declared that in the field, welding definitely can be substituted for riveting at a saving.

abstracts of CURRENT WELDING PATENTS

prepared by V. L. Oldham

Printed copies of patents may be obtained for 25¢ from the Commissioner of Patents, Washington 10, D. C.

2,498,241—Arc Spot Welding Apparatus—Hugh S. Bowen, Fairfield, Ala., assignor of 49% to Walter B. Bowen, El Paso, Tex.

This patent primarily relates to an electrode holder wherein an elongate sleeve of insulating material is provided and has an electrode holder positioned on the sleeve with an elongated guide being slideably carried on an end portion of the sleeve and forming an electrode receiving chamber. Other positioning means are provided for retaining an electrode on the device and for retracting an electrode into the electrode receiving chamber.

2,498,491—Welding Control—Julius Heuschkel, Pittsburgh, Pa., and Phillip M. La Hue, Denver, Colo., assignors to Westinghouse Electric Corp., East Pittsburgh, Pa., a corporation of Pennsylvania.

This patent relates to resistance welding apparatus wherein means are provided for indicating the thickness of the material to be welded. Valve means are positioned between the source of electrical energy and the welding machine for controlling the supply of electrical energy while a control network for the valve is coupled to and responsive to the means used to indicate the thickness of the material being welded so that the electrical energy supply is limited to a time interval dependent upon the thickness of the material to be welded.

2,498,492—Resistance Welding Metals of Different Thicknesses—Julius Heuschkel, Pittsburgh, Pa., assignor to Westinghouse Electric Corp., East Pittsburgh, Pa., a corporation of Pennsylvania.

The resistance welding method in this patent comprises the steps of applying a given force between welding electrodes which have metals of one thickness positioned therebetween and transmitting current of a given peak magnitude through the metals of the given thickness and varying the time that the current is transmitted through the metals dependent upon the thickness thereof.

2,498,905—Welding Apparatus—John H. Abbott, Los Angeles, Calif., assignor to Utility Appliance Corp., Los Angeles, Calif., a corporation of California.

Abbott's welding apparatus includes a structure having an operating station and intermittently-operating indexing means for moving successive portions of a workpiece to the operating station. A welding tool is connected to the apparatus for rotation between extended and retracted positions. Means are provided for rotating the welding tool from its retracted position to its extended position and back to its retracted position for each portion of the workpiece that has been moved to the operating station by the indexing means.

2,499,281—Flash Butt Welding Apparatus—Joseph J. Riley, Warren, Ohio, assignor to The Taylor-Winfield Corp., Warren, Ohio, a corporation of Ohio.

Riley's flash-butt welding apparatus includes a fixed platen, a carrier slideably mounted for movement toward and away from the fixed platen, and a movable platen slideably mounted on the carrier for movement toward and away from the fixed platen. Means are also furnished for moving the carrier to effect relative movement of the platens during the flashing period of the welding cycle, while other means on the carrier move the movable platen relative to the carrier during the upsetting period of a welding cycle to effect relative movement of the platens at that time.

2,499,524—Nozzle for Cutting Torches—Roy Pach, Minneapolis, Minn.

This novel type of a cutting torch nozzle includes a symmetrical, elongated body

that has a longitudinal bore therethrough for supplying an oxygen cutting stream under pressure. A secondary longitudinal passage is provided in this body for supplying a preheated gaseous mixture. A sleeve is provided for engaging with an outer portion of the said body and it provides, with an end portion of said body, a frusto conical bore that connects to the secondary passage of the body and terminates at a point adjacent the terminal end of the oxygen supply bore of the body.

2,499,577—Method of Inspecting Welds—Leslie Fine and Anthony R. Ozanich, Burbank, Calif., assignors to Menasco Mfg. Co., Burbank, Calif., a corporation of California.

This patent method comprises machining a shaving from the weld and embedding the spiral shaving in a moldable resinous plastic. Thereafter the molded plastic and shaving is cut along a line normal to the weld plane to expose a plurality of weld line surfaces and these exposed surfaces are etched to determine the presence of defects in the weld.

2,499,827—Welding Electrode for Cast Iron—Theodore Ephraim Kihlgren, Scotch Plains, N. J., assignor to The International Nickel Co., Inc., New York, N. Y. a corporation of Delaware.

This electrode is particularly suited for use in arc welding to produce crack-free welds on high phosphorous cast irons. The core wire contains about 40 to 75% nickel and the balance mainly iron. A flux coating encloses the core wire and contains 10 to 30 parts carbon, about 0.25 to 2.5 parts titanium, iron powder up to about 30 parts, about 45 to 85 parts slag-forming materials and a binder.

2,499,938—Flame Cutter—Leslie B. Ward, Perris, Calif.

This device includes means for supporting a pattern and means for supporting a workpiece in axial alinement with the pattern. A rocker arm is provided and pivoted intermediate its ends for swinging movement about a single axis at right angles to the axis of the pattern support. A pattern follower is carried by one end of the rocker arm to follow a pattern on the pattern support and a cutting torch is carried by the other end of the rocker arm to cut a workpiece placed on the workpiece support.

2,500,380—Method of Making Weld Rods—Jean Roelat, Mont-La-Ville, Switzerland.

This method of making weld rods include the provision of a cast aluminum ingot with a tapered axial hole extending the full length of the ingot and having a taper in the order of 1 to 4%. The hole in the ingot is filled with pulverant material having a fusion point below that of the metal in the ingot, the ingot is heated to a temperature below the fusion point of the flux material and thereafter extruding the composite ingot and pulverant mass by forcing it through a die and appreciably reducing the diameter of the composite ingot.

2,501,343—Resistance Welding Apparatus—Ernest M. Laughner, Jeannette, Pa., assignor to Westinghouse Electric Corp., East Pittsburgh, Pa., a corporation of Pennsylvania.

An electrode tip holder is provided in this patented device and includes a body member having a longitudinal bore with a tapered seat at one end for receiving a removable electrode tip and conduit means provide inlet and outlet connections with the bore for a cooling fluid. A striker is movably disposed in the bore and has an opening at one end communicating with one of the conduit means to direct cooling fluid. This striker projects from the body member at its other end whereas a ram is disposed to engage the projecting end of the striker and a single resilient metal bellows member connects the ram to the body member.

LIST OF NEW MEMBERS

March 1, to March 31, 1950

ANTHONY WAYNE

Albert, Ernest (B)
Campbell, John W. (C)
Shoup, Duke W. (B)

ATLANTA

Lumsden, Tom (C)
Nix, Fred (B)

BOSTON

Esselstyn, Stephen L. (B)
Lynds, Clayton F. (C)

CHICAGO

Retzlaff, Albert (B)
Root, Wilbur B. (C)
Ruesch, Earl G. (C)
Waterbury, C. L. (C)

CINCINNATI

Murdock, David (B)

CLEVELAND

Dempsey, William F. (C)
Jones, James L. (C)
Milligan, J. R. (C)
Sahli, H. E. (B)
Smith, Harlen C. (B)
Spitz, Karl (B)
Trout, Ralph (C)
Trump, Robert Coleman (C)

COLORADO

Smith, Clifford E. (C)

COLUMBUS

Adams, Francis E. (D)
Wright, Robert Raymond (D)

DALLAS

Horton, Malcolm Allan (B)

DAYTON

Caja, Joseph (D)
Gould, Francis L. (C)
Lenz, John L. (C)
Rice, James E. (D)

DETROIT

Adams, James L. (B)
Antal, Charles S. (C)
Beronus, Harry (B)
Drabicki, Edward J. (C)
Ferguson, Forrest B. (D)
Gamura, Michael Anthony (B)
Headapohl, John H. (C)
Hodgins, Fred M. (D)
Houpis, Constantine H. (B)
Jackson, Roy M. (B)
Keller, Louis A. (C)
Kennedy, Richard G. (B)
Klaas, James (B)
Leonard, Thomas J., Jr. (C)
Pavelka, Rudolph (B)
Pearce, R. D. (B)
Pitts, H. Charles (B)
Rose, Leon J. (C)
Robb, George D. (B)
Smith, William H. (C)
Stockton, R. J. (C)
Tuck, Fred L. (C)
Wilcock, James W. (C)

EASTERN ILLINOIS

Collins, Roland Dean (D)

HARTFORD

Fusher, George S. (B)
McCarthy, James C. (C)
Miller, Kenneth A. (B)

KANSAS CITY

Cortelyou, F. M., Jr. (C)
York, George A. (C)

LONG BEACH

Bunge, Kenneth D. (C)
Pupkoff, Henry, Jr. (C)
Skidmore, W. T. (C)

LOS ANGELES

Blackshaw, J. T. (C)
David, Barney (C)
Elem, R. H. (B)
Pinnell, L. T. (B)

MAHONING VALLEY

McClain, J. J. (C)

MARYLAND

Brandt, Vann H. (C)
Donegan, Thomas E. (C)
Mentzer, Jay K. (C)
Mercia, George J. (C)
Stevenson, W. E., Jr. (B)
Woodworth, Ered R. (C)

MICHIANA

Briehl, Neil J. (B)
Dixon, Thomas (B)
Schrader, Robert A. (C)

MILWAUKEE

Gradt, E. W. (B)
Hoeft, Woodrow (C)
McAtee, Elden (B)
Meyer, Orley R. (B)

NEW JERSEY

Tourison, Asher (B)

NEW YORK

Gandusio, Silvano (C)

NIAGARA FRONTIER

Wilson, Charles R. (C)

NORTHERN NEW YORK

Tillotson, Karl C. (C)

NORTHWEST

Feyereisen, L. W. (B)

NORTHWESTERN PENNSYLVANIA

Dylewski, Theodore A. (C)
Garnon, Fred W. (C)
Herman, Joseph (B)

OKLAHOMA CITY

Dennis, Gene R. (D)
Hejduk, Adolf (D)
Johnson, Harold A. (D)
Johnson, Verdean G. (D)
Newell, Oral Lee (D)
Raper, T. K. (D)

PITTSBURGH

Seaman, Frederic D. (C)

PORTLAND

Dickinson, Roy L. (B)
Epperly, Albert M. (B)
Williams, T. R. (B)

PUGET SOUND

Kilene, Oscar T. (C)
Kittelson, L. O. (C)
Miller, Stan (B)

RICHMOND

Boettcher, Harold A. (C)
Duckhardt, Richard W. (C)
Hathaway, E. I. (C)
Jones, John G. (C)

SAGINAW VALLEY

LaLonde, Robert R. (B)

ST. LOUIS

Fox, John J. (B)

SALT LAKE CITY

Carlson, Edwin (C)

SAN FRANCISCO

Faas, Bernard P. (C)
Watts, William J. (C)

SUSQUEHANNA VALLEY

Booth, George (C)
Schweyer, Robert P. (B)

SYRACUSE

Monson, Mel W. (C)
Whorrall, Richard (C)

TOLEDO

Morris, W. E. (C)

WASHINGTON

Bowron, Thomas W. (B)
Manion, James J. (C)

WESTERN MICHIGAN

Sybesma, Bert (C)

WICHITA

Lonsinger, Albert (B)
Manchester, Philip S. (B)
Palm, Warren S. (C)

NOT IN SECTIONS

Calhoun, John D. (C)
Christian, James H., III (C)
Gorczyca, Ernest (D)
Kaufer, Fred (B)
Koenigsberger, F. (B)
Turi, Enrico P. (C)
Waldbauer, Herbert (B)

Members Reclassified

During the month of March

CLEVELAND

Stringham, L. K. (C to B)

DETROIT

Mumford, William E. (C to B)

PITTSBURGH

Cable, H. E. (C to B)

ST. LOUIS

Rueff, Robert C. (C to B)

SOCIETY

West, Robert D. (C to B)

Employment Service Bulletin

Services Available

A-599. Metallurgical Engineer desires position in welding research and/or development. Will receive B.S. at Case, June, 1950. Practical training with ferrous metals, all-position electrodes. Thesis on arc-welding slags. Microphotography in connection with laboratory work. Member A.W.S. and A.S.M. Single, 21, excellent health. Will locate anywhere. Further details on request.

A-600. Is research or development in resistance welding your problem? My interests, education and experience are in that direction. Education includes B.S. in Electrical Engineering and advanced study in metallurgy and welding. Years of experience trouble shooting on resistance welding, machines and associated electronic controls. Summary of education and experience sent promptly on request.

A-601. Chief Metallurgist available. Last 12 years Chief Metallurgist, Engineering Contracting Co., suppliers of complete chemical plants and petroleum refineries. Consultant all problems involving solution of materials for corrosion or high-temperature service. Supervision of corrosion investigation in clients plants. Responsible for fabricating procedures, such as brazing, welding and heat treatment, for all ferrous and nonferrous materials used in construction of chemical and petroleum equipment. Organized and directed metallurgical laboratory and welding research laboratory.

A-602. Welding Engineer. College trained. Age 35. 12 years diversified experience in all phases of welding, brazing and soldering. Metallurgical welding research, engineering, production and processing experience. Requests position in executive capacity as works manager, or reporting to general manager of a small fabricating plant that desires high quality production work. Not a theoretical fanatic, but a good practical engineer. Married, family man, but will move anywhere, preferably in small western city.

A-603. Welding Sales Engineer. Age 32. B.S. in Metallurgical Engineering. Four years sales-service experience in electric welding—sold directly, trained distributors salesmen, conducted sales meetings, gave talks to AWS meetings; wrote published articles, sales and technical promotion literature, and advertising copy. Six years in welding applications, developments, and service engineering in mild, stainless, specialty steels, ferrous and nonferrous tools and dies, machining, and heat-treatment.

(*Continued from page 402*)

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Supplement to The Welding Journal, May, 1950

Stress Distribution Around Spot Welds

A study of the stresses around a spot weld when subjected to cyclic loading

by A. O. Bergholm, P. W. Swartz and G. S. Hoell

INTRODUCTION

IN VIEW of the absence of fundamental knowledge relating to the effect of resistance welding on plate joints, a somewhat limited research program was approved by the Welding Research Council, and carried out by the Franklin Institute Laboratories for Research and Development. A comprehensive program, including a great many tests of various joints under varying conditions of loading, would carry the work far beyond the scope for which funds were available. However, frequent failures at or around weld spots, especially where joints were subjected to variable stresses, or reversal of stresses, led to a decision to take a first step toward the determination of factors having significant influence on strength or weakness of a spot weld. With this in mind, it was decided to concentrate on the behavior of the stresses around the spot welds in two flat bars of low-carbon steel with two and with three weld spots. These were subjected to pull tests only, and the plan was to explore the field of stresses surrounding the welds with the idea that definite knowledge could be obtained as to how the stresses were distributed and whether the results so obtained could be used in pointing out possibilities for improvement or means of avoiding high stress concentrations.

A. O. Bergholm is Project Engineer; P. W. Swartz is Research Engineer; and G. S. Hoell was formerly Director of the Mechanical and Civil Engineering Division of the Laboratories, The Franklin Institute, Philadelphia, Pa.

Obviously, any measurement of principal stresses can be made directly along the axes of the principal stresses at various points, and the first problem then was to determine these directions. Photoelastic models suggested themselves for this purpose. Naturally, if two photoelastically sensitive plates were fastened together in a manner simulating a spot weld, the interference pattern of the two overlapping plates would be confused, and to obviate this, a clear plastic having negligible sensitivity to birefringence, such as Lucite or Plexiglas would be used for one of these plates and Columbia Resin CR39 would be used as the photoelastically sensitive material. A great deal of time was consumed in developing the proper technique of bonding these two plates, but after a satisfactory technique was developed, a dependable set of specimens was prepared, and examined in the polariscope. Since a method of determining magnitude of stresses in the field within the boundaries of the plate is based upon the change of thickness of the material at various points under examination, the photoelastic method could not be used to determine these magnitudes since the plates are overlapping. The purpose of using the photoelastic method therefore was limited to determination of the direction of the principal stresses with the idea that this would give exact information as to the direction in which strain gages on an actual steel specimen should be placed. Diagrams have been obtained of the isoclinics (loci of parallel principal stress direction) from which the principal stress trajectories have been determined in the case of a two-spot weld specimen. A great deal of care, however, had to be exercised to have the load

applied exactly in the line of the two welds in order to obtain a symmetrical pattern. In this connection it is realized that in practice such exact load application would seldom occur, but a complete examination of specimens with eccentric loading would carry the work beyond its present scope. In addition to the determination of the course of the stress trajectories, it is of interest to note that an isotropic point occurs at a point between the two weld spots (i.e., a point where stresses are equal in all directions; this may be visualized by referring to Fig. 7, point *A*).

In order to corroborate the results found by photoelastic means several steel specimens were sprayed with Stresscoat Enamel, which, when the specimens were loaded, would show cracks in the enamel at right angles to the principal tension stress direction. The results of application of Stresscoat enamel indicate general conformity with the results obtained from photoelastic models, and these were used as an indication for placing strain gages for actual measurement of magnitude of the stresses.

The strain gage tests have been carried out by the usual methods with a strain gage recorder, and the results appear on the subsequent pages.

There were strong indications that the application of a tension load caused a considerably greater stress concentration at the welds than would be generally realized. This was deduced from the fact that there were areas on the outer surfaces of the plates (see Fig. 4, also Tables 1 and 2) where high compression stresses were clearly indicated. Since under a tension load this cannot take place except from a bending moment, it can be concluded that a very high tension stress occurs near the welds where the two plates are in contact. A further exploration of this phase could not be included within the scope of the work, but a recommendation is made that this be subject to further study. It is entirely possible that the stress concentrations at the weld due to eccentric loading may prove to be of much greater importance than stress concentrations set up at the welds due to the transmittal of the normal stresses through a weld point in shear, or to stresses locked up due to thermal expansion and subsequent contraction around the weld.

While it was considered important, before undertaking any detailed studies, to plot the stress trajectories throughout the field surrounding the two or the three welds, the exploration of the magnitude of the stresses at any distance from the welds was considered to be of lesser importance at the present, and for this reason application of strain gages was limited to the stresses immediately around the welds.

Table 1—Tabulated Strain Data. Two-Spot Weld Specimen. Strain Values Are Recorded in Micro-Inches per Inch

Gages	*Loads, lb.* 1000	2000	3000	4000	5000
	Strain readings*				
1	−35	−70	−100	−120	−150
25	−30	−65	−90	−120	−150
2	−20	−50	−70	−90	−120
7	−35	−70	−90	−120	−140
24	−20	−50	−80	−110	−140
26	−15	−40	−70	−100	−130
3	+15	+40	+60	+80	+100
6	+20	+40	+55	+75	+90
23	+30	+40	+40	+40	+35
27	+40	+60	+80	+90	+95
4	+20	+40	+75	+110	+140
5	+20	+50	+80	+120	+150
22	+40	+70	+100	+120	+140
28	+45	+75	+100	+120	+125
8	+90	+180	+290	+400	+500
18	0	+40	+110	+175	+240
9	+70	+120	+180	+240	+290
14	+30	+50	+80	+110	+140
17	−5	−20	−20	−25	−25
19	0	0	+5	+20	+35
10	−30	−80	−120	−175	−220
13	−30	−80	−120	−160	−200
16	−20	−40	−55	−65	−80
20	−5	−25	−40	−60	−80
11	−130	−240	−310	−360	−390
12†					
15	−50	−80	−80	−60	−30
21	−70	−100	−100	−80	−65

* Plus (+) denotes tension strains. Minus (−) denotes compression strains.

Specimen yielded at 5500 lb., and all gages showed permanent set.

† Gage 12 was defective.

Table 2—Three-Spot Weld Specimen. Strain Magnitudes in Micro-Inches per Inch

Gages	*Loads, lb.* 1000	2000	3000	4000	5000
	Strain readings*				
1	0	0	0	0	−10
39	−20	−40	−55	−60	−80
2	−15	−30	−45	−55	−70
7	+20	+45	+60	+80	+65
38	−30	−45	−60	−65	−80
40	−20	−40	−55	−75	−80
3	0	0	0	+10	+20
6	+20	+35	+40	+50	+60
37	0	+15	+20	+40	+55
41	+10	+20	+40	+45	+60
4	+15	+40	+55	+75	+80
5	+25	+45	+60	+70	+85
36	+50	+80	+100	+120	+150
42	+40	+70	+100	+110	+140
8	+40	+110	+180	+260	+330
32	+80	+140	+210	+270	+345
9	+35	+60	+85	+120	+150
14	0	+15	+20	+40	+60
31	0	+15	+30	+40	+65
33	+55	+90	+120	+150	+200
10	+20	+25	+30	+25	+30
13	+15	+20	+15	+15	+20
30	0	0	0	0	0
34	0	+10	+10	+5	+10
11	+20	+40	+60	+80	+110
12	+20	+45	+70	+95	+130
29	+30	+55	+80	+120	+140
35	+20	+40	+65	+90	+120
15	+35	+100	+180	+275	+360
25	+50	+120	+195	+280	+370
16	+35	+60	+90	+120	+150
21	0	+5	+20	+50	+70
24	+15	+40	+55	+95	+120
26	+35	+60	+95	+140	+170
17	−40	−70	−105	−130	−160
20	−30	−50	−60	−80	−80
23	+15	+15	+15	0	−20
27	−40	−90	−130	−160	−200
18	−120	−160	−165	−145	−130
19	−90	−115	−110	−80	−40
22	−20	−25	−15	+10	+50
28	−60	−100	−110	−105	−90

* Plus (+) denotes tension strains. Minus (−) denotes compression strains.

Specimen yielded at 5500 lb., and most of the gages showed a permanent set.

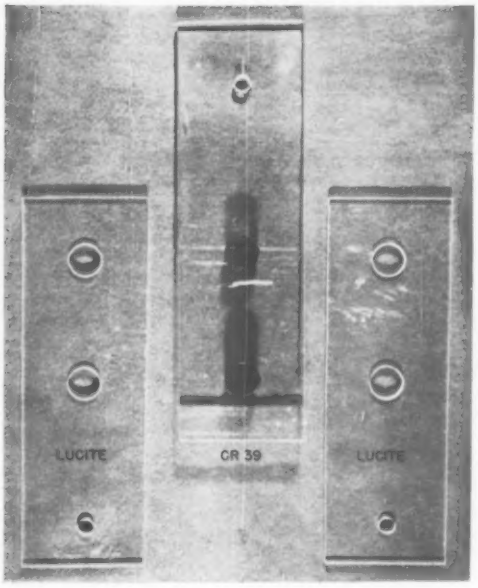


Fig. 1 Disassembled photoelastic model

Center plate, CR39, 1/4 in. thick; outer plates, Lucite, 3/16 in. thick

No definite recommendations seem yet to be in order with a view to improving welding design practice or for the purpose of avoiding such stress concentrations as might lead to fatigue failures, without further examination of the stresses due to bending moments set up by eccentric loading. Also, the appearance of an isotropic point existing between the welds would indicate that a major change in the stress trajectories would take place in case a hole is drilled at some point between the welds and that this change may very well reduce concentrations. An extension of this research program should include exploration of this phase.

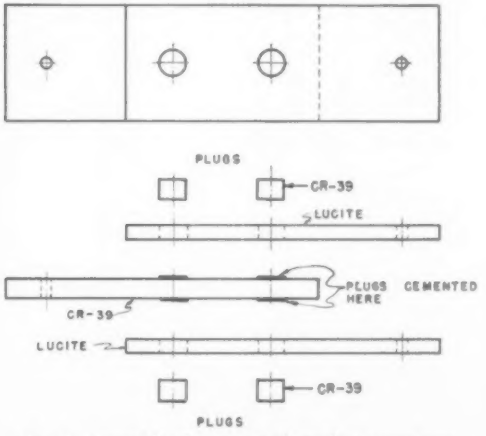


Fig. 2 Assembly of two-spot photoelastic specimen

Figure 3

The following contains a description of the specimens used, the test procedure and a general description of results, with further discussion of the work.

SPECIMENS

Photoelastic Specimens

Specimens were made from combination of the Columbia Resin CR39 and Lucite. By the photoelastic method it was necessary to select a material, representing one of the welded plates, which was photoelastically sensitive, while the other, such as Lucite, has negligible birefringence properties and will therefore cause no disturbance of the continuity of interference lines in the CR39 half of the model. The parts making up these plastic models are shown in Fig. 1, while Fig. 2 is a line drawing showing the same parts. Figure 3 shows the continuity of interference lines where the edge of the Lucite plates overlap the CR39 plate. The plastic plugs shown in Fig. 2 were cemented to the CR39 plate and fitted snugly into the two holes of the Lucite plates. At an earlier stage of this investigation it was considered important that both materials have the same elastic extension under the same load, and tests were therefore made of the moduli of elasticity of the two materials. These were found to be as follows:

Modulus of Elasticity CR39, psi	290,000
Modulus of Elasticity Lucite, psi	380,000

For a thickness of 1/4 in. of the CR39 plate this would roughly correspond to a thickness for the Lucite plate of 3/16 in. It became apparent, however, that the use of a single lap welded joint would cause a transverse bending moment when loaded, which would give unreliable results in a photoelastic test, and on the assumption

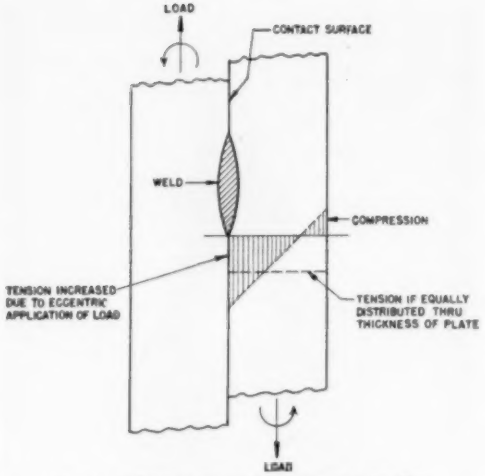


Fig. 4 Influence on weld of eccentric loading

that the principal stress directions would change but little with a change in the relative elastic yields of the two materials, it was considered desirable to use a plate of Lucite on both sides of the CR39 plate instead of only one, in order to obviate this bending moment. Specimens were made up representing two-spot and three-spot weld patterns, Fig. 6.

With the idea of investigating stress concentrations at points near the welds where the two welded plates are in contact, consideration was given to a specimen as shown in Fig. 5 where the points marked *A* would conceivably show high concentrations. However, because of the time required to develop the proper technique, and the time required for machining and preparing such specimens for test, this phase of the project was abandoned for the present.

Steel Specimens

Low-carbon steel bars $2^3/_4$ in. wide and $^1/_8$ in. thick were used for making up specimens shown in Fig. 6. The welds were made under laboratory conditions to the following specifications:

Electrode force, lb.	3500
Welding time, cycles	25
Minimum shear strength, lb.	6500–7000
Welding current, amp.	2200
Electrodes	$^1/_2$ in. diameter with 3-in. radius curvature

The purpose of making these models was twofold: First, to spray them with Stresscoat Enamel, subject them to loads sufficient to produce strain cracks and to determine stress trajectories, in the region of the weld thus verifying the results made by photoelastic means; secondly, to attach electric strain gages in the direction

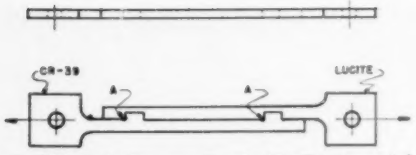


Fig. 5 Model of slice cut longitudinally through weld spots by planes normal to surface of plates

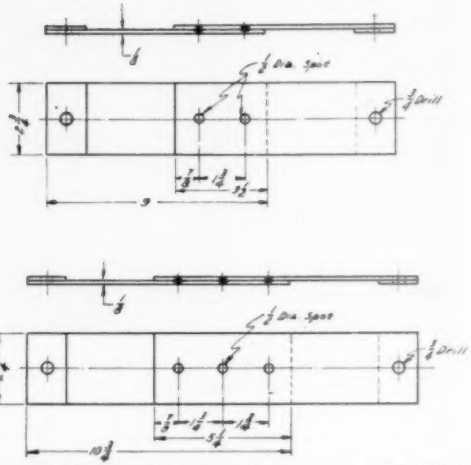


Fig. 6 Sketches of two- and three-spot welded-steel specimens

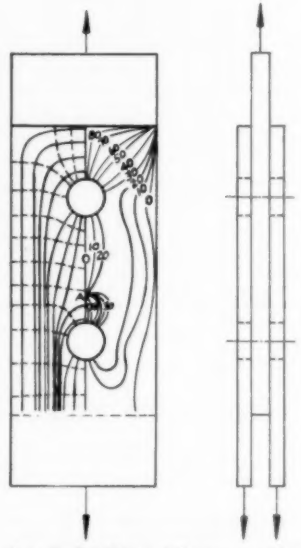


Fig. 7 Isoclinics (shown on the right side) and principal stress trajectories in a two-spot lap-welded specimen. (Point A is an isotropic point)

of the principal stresses, to obtain the magnitudes of these stresses with respect to a known load on the bars in tension.

TEST PROCEDURE AND RESULTS

Photoelastic

The photoelastic specimens were tested in the polariscope to loads of approximately 75 to 100 lb. and the isoclinics at 10° intervals were recorded by photographs.

The directions of the principal stresses plotted from the specimens for a two-spot weld pattern are illustrated in Fig. 7. On the right-hand side of the model, the isoclinics are shown at intervals of 10° inclination between principal stress directions and axes of polarization; on the left-hand side, the paths of the stress trajectories as constructed from the isoclinics. The results were verified by the study of a considerable number of models. Similar models of three-spot weld patterns were also made, but the results were not sufficiently consistent to be considered reliable and are therefore not included in this report.

Stresscoat Enamel

The steel specimens were sprayed with Stresscoat Enamel and subjected to tension tests. The two-spot weld joints were limited to a 4000-lb. load and the three-spot weld joints to a 7000-lb. load to prevent plastic yield of the welds. The appearance of strain cracks and the corresponding loads were recorded.

Strain cracks in the two-spot welded joint first appeared in the spot nearest the end of the plate at 2900 lb. load. Calibration of the coating showed a threshold sensitivity value of 0.00075 in. per inch strain. Stress at that point at 2900-lb. load is 22,100 psi. Similarly, the three-spot weld joint showed strain cracks in the spot nearest the end of the plate at 4000-lb. load. The calibration of this coating showed a threshold value of 0.00085 in. per inch strain and thus a stress of 25,000 psi.

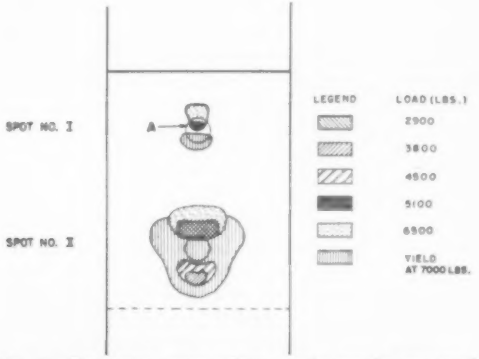


Fig. 8 Composite areas where strain cracks appeared under the tension loads listed (stress coat enamel on two-spot welded specimen)

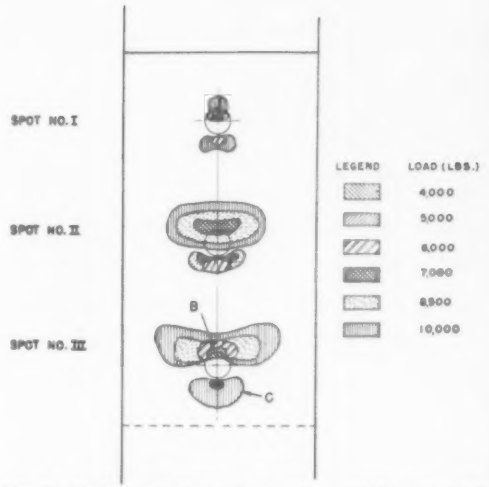


Fig. 9 Composite areas where strain cracks appeared under the tension loads listed (stress coat enamel on three-spot welded specimen)

Areas where strain cracks first appeared at various loads were noted, and from this information tabulations 3 and 4 were prepared to show the stress that would have existed at these points under an arbitrary load of 5000 lb. The results are not conclusive, not consistent when comparing the location on the two- and three-spot specimens where stress concentrations are first set up, viz., at points *A* in Fig. 8 and *B* in Fig. 9. A great number of tests would probably point to the locations where failures may be expected, but variable factors entering into the making of the weld, and the degree of bending of the plates taking place under load as in Fig. 4, seem to indicate that a dependable degree of certainty can be obtained only through a continued long-range research program. As an example of a condition where further investigation is indicated, it may be noted that at point *C* below Spot III, Fig. 8, it took a very high tensile load to produce strain cracks in the enamel, while the small narrow strip between this and the weld itself started out with compression stresses as determined by the electrical strain gages. It may well be,

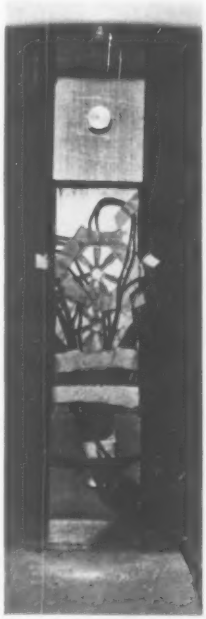


Fig. 10 Two-spot welded specimen with strain gages attached, shown in tensile-test machine

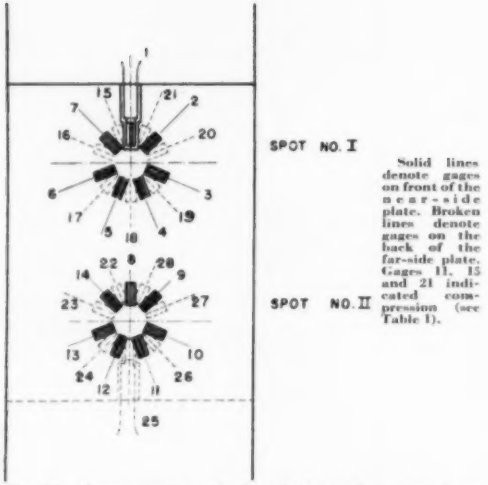

SPOT NO. I
SPOT NO. II
Solid lines denote gages on front of the near-side plate. Broken lines denote gages on the back of the far-side plate. Gages 11, 15 and 21 indicated compression (see Table 1).

Fig. 11 Arrangement of electrical strain gages 1 to 28, inclusive, on two-spot welded specimen

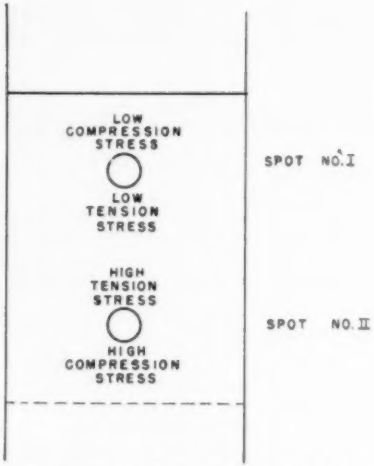


Fig. 13 Summary of relative magnitudes of stresses in regions of interest on two-spot welded plate

therefore, that the bending of the plates which always takes place in a single lap-welded joint has a decided detrimental influence in combination with direct shear and that a further study of the problems would lead to changes in methods of design rather than to avoidance of failures through reduction of permissible loads.

Electrical Strain Gage Method

The results obtained from the photoelastic and the Stresscoat Enamel analysis established directions for the placing of the electrical strain gages. The strain readings were recorded with an Automatic Switching Unit and a Scanning Recorder. Figure 10 shows the specimen with the gages attached. The loads on the specimens were added in 1000-lb. increments and removed after the recording of each cycle. Additional increments were added and strains recorded until a gage showed permanent set, at which time test was discontinued.

The arrangement of the strain gages are shown in Figs. 11 and 12. The solid lines denote gages on the front of the near-side plate as shown. The broken lines show location of gages on the back of the far-side plate. The ends of the gages were placed on the edges of the weld spots.

These plots represent the principal results of the electrical strain gage tests. The magnitudes of the strains for various tension loads are contained in tables 1 and 2. The gage readings are tabulated in groups of symmetrical positions on the spot-welded plates. For example, on the two-spot-welded specimen Gage 1 records the strain on one side of the plate and Gage 25 records the strain on the other plate at symmetrical positions. Tension strains are designated by plus (+) signs and compression strains designated by minus (−) signs. It will be noted that symmetrical gages do not in all cases record identical strains, probably because of slight misalignment of the loading pins with the actual areas of adhesion of the weld spot, or instrumentation discrepancies, and does not seem to have specific significance. Figures 13 and 14 show a general distribution of tension and compression in the regions surrounding the welds.

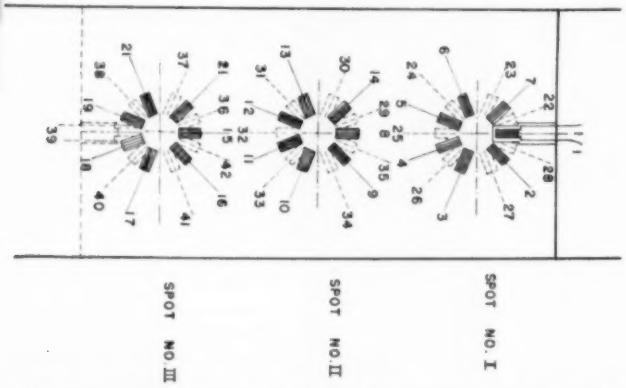


Fig. 12 Arrangement of electrical strain gages on three-spot welded specimens

Solid lines denote gages on front of the near-side plate. Broken lines denote gages on the back of the far-side plate.

DISCUSSION

The isoclinics and stress trajectories obtained for the two-spot specimen by photoelasticity are considered satisfactory. No doubt improvements in techniques in bonding could be accomplished so as to obtain more consistent results, especially for the three-spot specimens. The difficulty in obtaining good results with

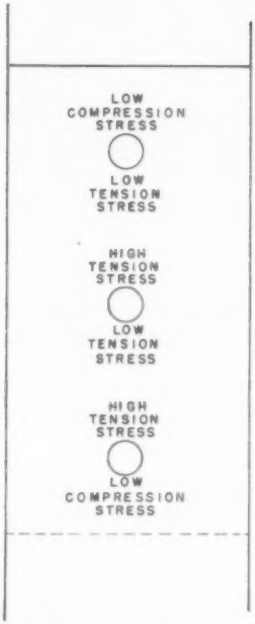


Fig. 14 Summary of relative magnitudes of stresses in regions of interest on three-spot welded plate

the latter was probably caused by the inaccuracies inherent in the use of plastics, and the mechanical difficulties in placing the plugs to take loads proportional to the loads on the welds in the steel specimens.

The sketches of the contours of the strain cracks as obtained from the Stresscoat enamel (see Figs. 9 and 10) reveal that the highest stresses occur around Spot II on the two-spot specimen (neglecting the high stress at the boundary of the weld at point *A* of Spot I) and spots II and III on the three-spot specimen. This agrees with the results from the electrical strain gage work. However, the magnitudes of the stresses shown by the Stresscoat enamel are greater than those recorded by the electrical strain gages for the same load. This discrepancy is due to the fact that the electrical strain gages used record an average stress over a $\frac{1}{4}$ in. length, while in the case of Stresscoat enamel, the stress indicated is that existing at a point, and this stress is extrapolated to a stress at a 5000-lb. load for the convenience of comparison.

The strain gage readings taken on the two-spot joint revealed several interesting facts about the magnitudes of the stresses on the surface of the plates: the maximum tension stresses occur along the lines of the applied force in the regions between the spot welds. Referring to Fig. 11, the two-spot welded plate showed the maximum tension stress above Spot II according to gage 8, and a lower tension stress below Spot I according to gages 4 and 5. This is corroborated by stresses shown in Table 3, which were obtained from Stresscoat test. Referring to Fig. 12, the three-spot welded plate

Table 3—Stresses on Two-Spot Welded Plate as Shown by Stresscoat Enamel (See Photograph of Strain Cracks, Fig. 9)

Load, lb.	*Match strain, in./in.*	*Strain at 5000-lb. load, in./in.*	*Apparent stress at 5000-lb. load, psi.*
2900	$0.00075 \times \frac{5000}{2900}$	$= 0.00129 \times 29.5 \times 10^6$	= 38,000
3800	$0.00075 \times \frac{5000}{3800}$	$= 0.00099 \times 29.5 \times 10^6$	= 29,000
4500	$0.00075 \times \frac{5000}{4500}$	$= 0.00083 \times 29.5 \times 10^6$	= 24,500
5100	$0.00075 \times \frac{5000}{5100}$	$= 0.00074 \times 29.5 \times 10^6$	= 22,000
6500	$0.00075 \times \frac{5000}{6500}$	$= 0.00058 \times 29.5 \times 10^6$	= 17,000
Yield	$0.00075 \times \frac{7000}{5003}$	$= 0.00054 \times 29.5 \times 10^6$	= 16,000

Modulus of elasticity = 29,500,000 psi. Yield strength = 30,000 psi.

Table 4—Stresses on Three-Spot Welded Plate as Shown by Stresscoat Enamel (See Photograph of Strain Cracks, Fig. 10)

Load, lb.	*Match strain, in./in.*	*Strain at 5000-lb. load, in./in.*	*Apparent stress at 5000-lb. load psi.*
4,000	$0.00085 \times \frac{5000}{4000}$	$= 0.00106 \times 29.5 \times 10^6$	= 31,000
5,000	$0.00085 \times \frac{5000}{5000}$	$= 0.00085 \times 29.5 \times 10^6$	= 25,000
6,000	$0.00085 \times \frac{5000}{6000}$	$= 0.00071 \times 29.5 \times 10^6$	= 21,000
7,000	$0.00085 \times \frac{5000}{7000}$	$= 0.00061 \times 29.5 \times 10^6$	= 18,000
8,500	$0.00085 \times \frac{5000}{8500}$	$= 0.00050 \times 29.5 \times 10^6$	= 15,000
10,000	$0.00085 \times \frac{5000}{10,000}$	$= 0.000425 \times 29.5 \times 10^6$	= 13,000

Modulus of elasticity = 29,500,000 psi. Yield strength = 30,000 psi.

showed maximum tension stresses above spots II and III according to gages 8 and 15. The strains in the plate adjacent to the weld where the load enters the joint *is compression* and not tension. Referring again to Fig. 11 for the two-spot weld specimen, this location of compression area is immediately below Spot II and shown by gages 11 and 12. Similarly for the three-spot joint, Figs. 9 and 12, such compression stress exists below Spot III according to gages 18 and 19. The probable reason for this has already been discussed in connection with Fig. 4. Table 4 indicates the magnitude of these compression stresses.

These investigations so far lead to a conclusion that single laps of spot-welded joints are inherently weak due to the unavoidable bending of the plates; that in important structures double laps (one plate sandwiched between two plates) will reduce considerably the high stress concentrations set up at the weld spot; that relief of stress concentration may be obtained by proper removal of material (such as drilled holes) to redistribute the stresses near the weld; and finally that the joining of two plates by one row of resistance spot welds is inherently unsound when used for important structures carrying greatly variable loads or reversal of stress.

Tests of Fillet Welds on Aluminum Alloy 61S-T6 Plate

Static tests of argon-shielded tungsten-arc transverse and longitudinal fillet welds on aluminum alloy 61S-T6 plate

by R. L. Moore and J. M. Pickett

Synopsis

The tests described were undertaken to obtain additional information on two phases of welding of interest in the design of welded aluminum alloy 61S-T6 construction: (1) the effect of transverse fillet welds on the tensile strength of plating, and (2) the strength of fillet welds under longitudinal shear. In some respects the work parallels that reported by Moore[1] and Hartman, *et al.*[2]

In the tests of specimens having transverse welds, plate efficiencies ranging from 58 to 79% were observed, depending on the size and spacing of the welds. The smaller the size and length of weld used on a plate of given width, the smaller the loss in static strength as a result of welding.

The shear tests indicated ultimate static strengths of about 14,000 psi. on the throat area of all welds.

INTRODUCTION

RECENT developments in gas-shielded arc-welding procedures have opened new fields for welded aluminum-alloy construction. This is particularly true in the marine field where the absence of welding flux eliminates a corrosion problem commonly associated with the older types of welding.

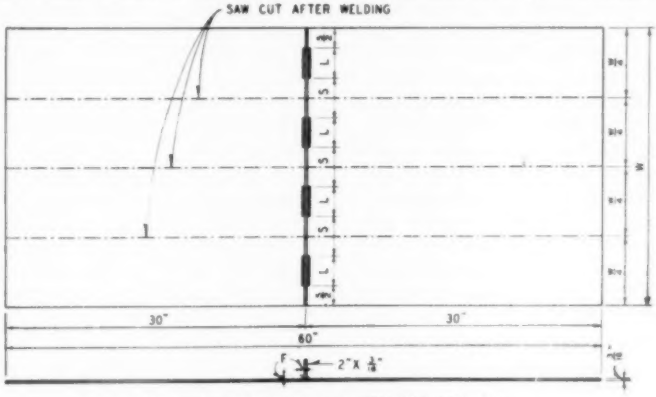
The design of welded structures of heat-treatable aluminum alloys requires information not only on the strength of the welds but also on the effect of heat of welding on the mechanical properties of the parent material. Although some data have been published on the strength characteristics and heat effects of unshielded metal-arc welds on aluminum,[1, 2] corresponding data are not generally available for welds made by the newer gas-shielded methods.

The object of the tests described in this paper was to obtain information on two aspects of argon-shielded tungsten-arc welding as applied to aluminum alloy 61S-T6 plating: first, to determine the reductions in the static tensile strength of plating to be expected as a result of fillet welding normal to the direction of loading and, second, to determine the static shear strength of different sizes of fillet welds.

The effect of heat of welding on plate strengths is an important factor in many structural applications. In ship construction, for example, the fillet welds used to attach transverse stiffeners to the underside of deck plating may have a significant influence on the effectiveness of such plating in resisting bending of the ship as a whole. Intermittent welding, if adequate from the standpoint of shear transfer, would seem to be preferable to continuous welding in such applications because of the smaller amount of heat involved. Data on the shear strength of fillet welds are necessary, of course, to determine the size and length of weld for any particular design.

SPECIMENS AND WELDING PROCEDURE

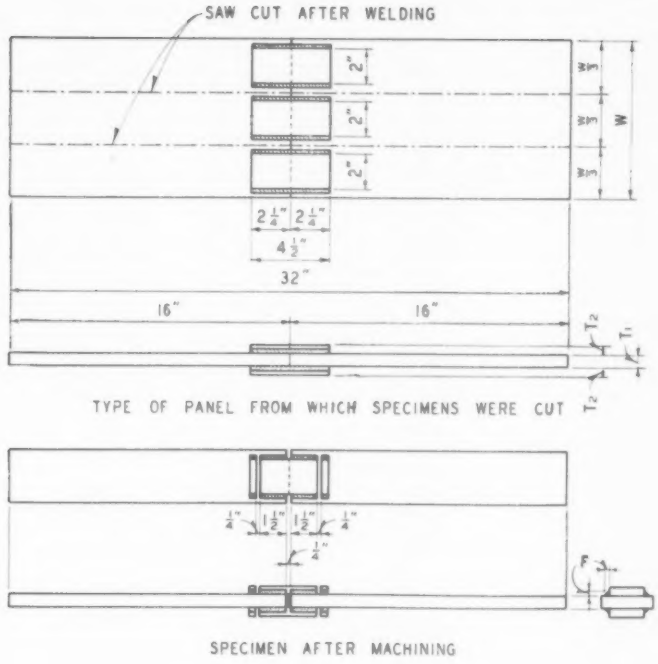
Figures 1 and 2 indicate the types and sizes of specimens used in these tests, as well as the welding and machining procedures following in their fabrication. All welds were made by the argon-shielded tungsten-arc process, using 43S (5% silicon) aluminum alloy wire. The $^3/_{16}$- and $^1/_4$-in. fillets on the specimens designed



SPECIMEN NUMBER	NUMBER OF WELDS	F	L	S	W	W/4
1A, B, C, D	4	3/16"	3"	6"	36"	9"
2A, B, C, D	4	3/16"	3"	5"	32"	8"
3A, B, C, D	4	3/16"	3"	4"	28"	7"
4A, B, C, D	4	3/16"	3"	3"	24"	6"
5A, B, C, D	4	1/4"	3"	6"	36"	9"
6A, B, C, D	4	1/4"	3"	5"	32"	8"
7A, B, C, D	4	1/4"	3"	4"	28"	7"
8A, B, C, D	4	1/4"	3"	3"	24"	6"
9A, B, C, D	CONTINUOUS	3/16"	24"	–	24"	6"
10A, B, C, D	CONTINUOUS	1/4"	24"	–	24"	6"
11A, B, C, D	NONE	–	–	–	24"	6"

Fig. 1 Specimens for tensile tests of aluminum alloy 61S-T6 plates with transverse fillet welds

R. L. **Moore** is with the Aluminum Research Laboratories and J. M. **Pickett** is with the Development Division of the Aluminum Company of America, New Kensington, Pa.



SPECIMEN NUMBER	F	T_1	T_2	W/3
1A, B, C	3/16"	1/8"	1/8"	3"
2A, B, C	1/4"	3/4"	1/4"	3"
3A, B, C	3/8"	1"	3/4"	3"
4A, B, C	1/2"	1 1/4"	1"	3 1/2"

Fig. 2 Specimens for shear tests of fillet welds on aluminum alloy 61S-T6 plates

to show the effect of transverse welds on tensile strength were made in one pass, using a 1/4-in. diameter tungsten electrode, 14 liters of argon per minute and a current value of 250 amp. (a. c). All specimens of this type were welded without preheat.

The welds on the specimens designed for shear-strength determinations were made in one pass with the exception of the 1/4-in. size, for which two passes were required. A 1/4-in. diameter tungsten electrode was used for the 3/16-in. fillets, whereas a 5/16-in. diameter tungsten electrode was used for all other sizes. Argon gas at a rate of 18 liters per minute was used with the following current values (a. c.): 400 amp. for the 3/16-in. welds, 450 amp. for the 1/4-in. welds, 500 amp. for the 3/8-in. welds, 550 amp. for the 1/2-in. welds. All specimens of this type were preheated before welding since preliminary tests indicated that the welds could be completed in a shorter time following that procedure. Although the preheat in the vicinity of the first welds made on any panel was kept to about 400° F., measurements during welding indicated temperatures as high as 500 to 600° F.

Alcoa Alloy 61S (Federal Specification QQ-A-327), consisting nominally of 0.25% copper, 0.6% silicon, 1% magnesium, 0.25% chromium and the balance aluminum, was used for the material in these specimens because it is the most widely used of the heat-treatable aluminum alloys in applications involving welding.

TEST PROCEDURE

All tests were made in an Amsler universal testing machine of 300,000-lb. maximum capacity, equipped with face-aligning wedge-type grips capable of handling flat specimens in widths up to 5 7/8 in. In order to accommodate the specimens having transverse welds, therefore, it was necessary to machine down the widths at the ends to 5 7/8 in. Paddle-shaped reinforcing plates were attached to the ends of the 8- and 9-in. wide specimens by bolts through the unreduced section so that fractures would be obtained in the weld zones at the center, rather than at the reduced width at the grips. In the case of specimens 11-A, -B and -C the width over the middle 36 in. of the length was reduced to 5 in. in order to prevent fracture at the gfips.

Deformations were measured along the edges of all specimens by means of a manually operated 2-in. strain gage. One division on the dial corresponded to a change in gage length of 0.0002 in. In the case of the specimens having transverse fillet welds, the observed changes in gage length were reduced to unit values for comparative purposes, even though it was recognized that the unwelded specimens were the only ones for which the assumption of uniform strain over the gage lengths could reasonably be made. The changes in gage length on the shear specimens were used as measured, without reduction to unit values, since they represented an even more unknown distribution of shearing and tensile strains.

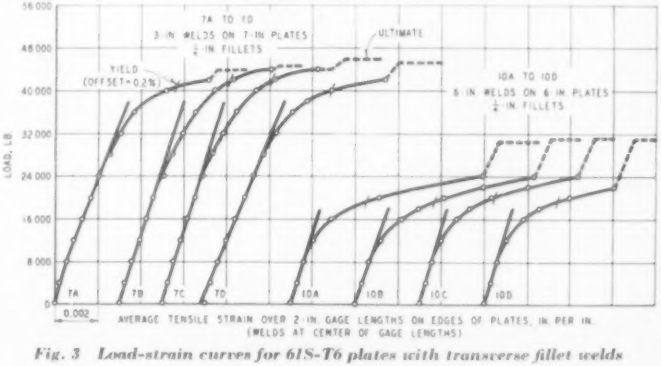


Fig. 3 Load-strain curves for 61S-T6 plates with transverse fillet welds

Table 1—Results of Alcoa Tests to Determine Effect of Transverse Fillet Welds on Tensile Strength of 61S-T6 Plate

Specimens	Nominal dimensions, in.: Size of weld	Over-all width of plate	Length of weld	Measured size of weld, in.	Average yield strength,* psi.	Average ultimate strength, psi.	Average elongation on edges, %: 2-in. length	10-in. length
1-A, -B, -C, -D	3/16	9	3	0.21–0.27	36,800†	36,900	10.6	3.0
2-A, -B, -C, -D	3/16	8	3	0.22–0.26	35,500†	35,400	9.5	2.6
3-A, -B, -C, -D	3/16	7	3	0.24–0.25	32,600	34,100	10.3	2.8
4-A, -B, -C, -D	3/16	6	3	0.24–0.25	30,300	33,200	11.0	2.5
5-A, -B, -C, -D	1/4	9	3	0.29–0.31	34,700	35,600	9.8	2.9
6-A, -B, -C, -D	1/4	8	3	0.31–0.33	33,300	34,400	9.8	2.8
7-A, -B, -C, -D	1/4	7	3	0.30–0.32	30,500	33,300	10.1	2.6
8-A, -B, -C, -D	1/4	6	3	0.29–0.33	25,800	31,000	12.5	2.8
9-A, -B, -C, -D	5/16	6	6	0.22–0.23	20,200	29,000	9.4	1.9
10-A, -B, -C, -D	1/4	6	6	0.28–0.30	17,000	26,900	10.8	2.2
11-A, -B, -C	No welds	5	..	...	41,300	46,700	22.0	14.4
11L-A, -B‡	No welds	1/2	..	...	42,500	48,100	18.0	...
11T-A, -B‡	No welds	1/2	..	...	39,300	47,100	16.3	...

* Yield strengths based on strains measured over 2-in. gage lengths on edges of plates (see Fig. 3).
† Determination from a single test. Corresponding ultimate-strength values are average of 4 tests.
‡ Specimens 11L-A, -B and 11T-A, -B were A.S.T.M. standard 1/2-in. wide, sheet-type tensile-test specimens. "L" indicates direction parallel to direction of rolling (also parallel to 5-in. wide specimens 11-A, -B, -C); "T" indicates direction normal to direction of rolling.

RESULTS AND DISCUSSION

Effect of Transverse Fillet Welds on Tensile Strength of Plate

Table 1 and Figs. 3 to 5 give the results of the tests designed to show the effect of transverse fillet welds on the tensile strength of 61S-T6 plating. The strengths obtained for the unwelded samples indicated that the material used was representative of commercial 61S-T6 plate. The average yield and ultimate strengths for both the 5 in. wide and the parallel 1/2-in. wide specimens averaged within about 5% of values considered typical for this alloy and temper.[3]

It should be pointed out that the welds were all somewhat larger than specified. The fillets which should have been 3/16 in. were more nearly 1/4 in.; those which should have 1/4 in. were more nearly 5/16 in. Since size of weld has a significant effect on plate strengths, it may be assumed that the reductions in strength here indicated were greater than would have been obtained had the actual sizes of weld been kept within the limits specified. Because of the adverse effects of heat of welding on 61S-T6, or any other heat-treatable aluminum alloy, the importance of maintaining minimum sizes of weld consistent with shear-strength requirements and good welding practice cannot be overemphasized.

The values of yield strength given in Table 1 correspond to an offset of 0.2% from the initial straight-line portion of the load-strain curves. A typical set of curves of this type is shown in Fig. 3. In the case of the unwelded specimens this procedure gave values consistent with the usual interpretation of yield strength as applied to aluminum alloys. In all others it merely provided an arbitrary, quantitative basis for comparing general yield characteristics.

Stress-strain curves of the type shown in Fig. 4 provide a more direct comparison of the general yield tendencies of the different groups of specimens than can be obtained from the individual load-strain curves. Those shown for the specimens of unwelded plate and continuously welded plate having 1/4-in. fillets merit the most attention because they represent the extreme limits of yielding phenomena encountered. The yield tendencies of plates with intermittent welds would be expected to lie between these two limiting curves and for the most part such a result was obtained. First yielding in the plates having 1/4-in. welds across the entire width appears to have begun at stresses in the vicinity of 7000 psi. According to Table 1, however, the yield strengths for these specimens, based on 0.2%-offset strains

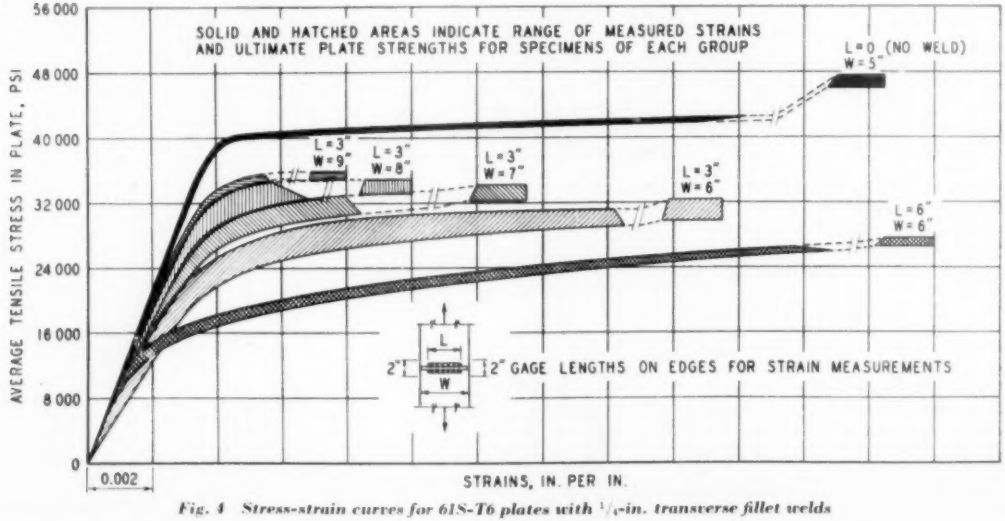

SOLID AND HATCHED AREAS INDICATE RANGE OF MEASURED STRAINS AND ULTIMATE PLATE STRENGTHS FOR SPECIMENS OF EACH GROUP
L = 0 (NO WELD) W = 5"
L = 3" W = 9"
L = 3" W = 8"
L = 3" W = 7"
L = 3" W = 6"
L = 6" W = 6"
L
W
2"
2" GAGE LENGTHS ON EDGES FOR STRAIN MEASUREMENTS
AVERAGE TENSILE STRESS IN PLATE, PSI
56 000
48 000
40 000
32 000
24 000
16 000
8 000
0
0.002
STRAINS, IN. PER IN.

Fig. 4 Stress-strain curves for 61S-T6 plates with 1/4-in. transverse fillet welds

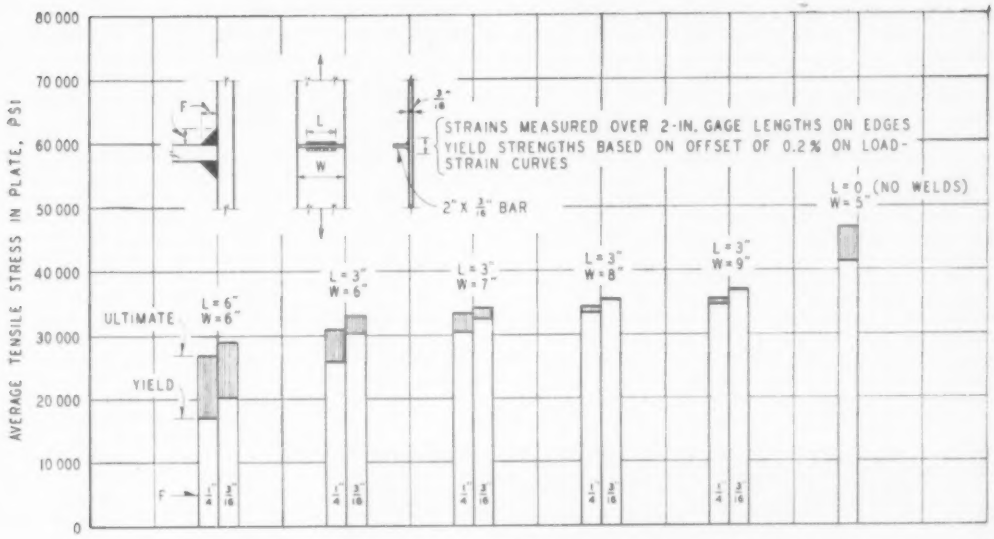

AVERAGE TENSILE STRESS IN PLATE, PSI
80 000
70 000
60 000
50 000
40 000
30 000
20 000
10 000
0
STRAINS MEASURED OVER 2-IN. GAGE LENGTHS ON EDGES
YIELD STRENGTHS BASED ON OFFSET OF 0.2% ON LOAD-STRAIN CURVES
2" x 3/16" BAR
ULTIMATE
YIELD
L = 6" W = 6"
L = 3" W = 6"
L = 3" W = 7"
L = 3" W = 8"
L = 3" W = 9"
L = 0 (NO WELDS) W = 5"

Fig. 5 Average tensile strengths of 61S-T6 plates with transverse fillet welds

over 2-in. gage lengths, averaged 17,000 psi. Although the distribution of strain over these gage lengths was not known, there would seem to be no question but that the local permanent set in the most heat-affected zones that contributed most of the observed yielding was greater than 0.2%. The yield strength corresponding to a set of 0.2% on a shorter gage length, therefore, should be less than the value of 17,000 psi. given in Table 1, yet greater than the first-yield value of 7000 psi. indicated above. The corresponding yield strength for the plates having 3/16-in. welds across the entire width appeared to lie between the stress limits of about 13,500 psi., which marked the beginning of yielding, and 20,200. psi., which is the offset-yield value given in Table 1. The ratio of almost two to one in the stresses corresponding to first yielding for the two sizes of fillet weld emphasizes more strikingly that either the offset-yield values or the ultimate strengths the importance of keeping sizes of fillet weld to a practical minimum.

Figure 5 is a bar graph which summarizes the significant results and comparisons to be made from this series of tests. It is at once apparent that the 1/4-in. fillets produced greater reductions in yield and ultimate plate strengths than did the 3/16-in. size. The average strengths for the 1/4-in. welds were smaller, by amounts ranging from 3 to 16% than the corresponding values obtained for the 3/16-in. welds.

It is also quite evident that the greatest reductions in plate strengths were obtained for the specimens welded across the entire width. The average yield value for the specimens having 1/4-in. welds, for example, was only about 41% of the yield strength of unwelded plate; the corresponding ultimate strength was about 58% of the tensile strength of unwelded plate. These welded plate efficiencies were the lowest observed. The efficiencies for the continuous welds of the 3/16-in. nominal size were 49 and 62% for the yield and ultimate strengths, respectively.

The average ultimate strengths of 26,900 and 29,000 psi. indicated for the continuously welded specimens are considerably above the value of 18,000 psi. considered typical for annealed 61S[3] and which represents the lower limit of strength to be expected under extreme conditions of heat of welding. It is also of interest to point out that these ultimate strengths are of about the same magnitude as have been observed for butt-welded joints in 61S-T6 plate.[2]

Figure 5 indicates also the nature of the increases in plate strength to be obtained by the use of intermittent rather than continuous welding. As might reasonably be expected, the smaller the amount of welding used in proportion to the width of plate, the more closely the plate strengths will approach those of unwelded material. The maximum efficiencies indicated by the ultimate strengths of the 9-in. wide specimens, having 3-in. long welds, were 76 and 79% for the two sizes of fillet. It will be seen that the yield values for these wide specimens were almost equal to the ultimate strengths.

Although mention has been made of the range of over-all plate efficiencies developed, some speculation regarding the distribution of load between the welded and unwelded portions of the intermittently welded specimens is of interest. Table 2 shows the average efficiencies estimated for the component parts as well as for the specimens as a whole. It was assumed that the ultimate strengths per inch of weld were the same for the intermittent as for the continuously welded specimens. Furthermore, the load-carrying capacity

Table 2—Summary of Welded Plate Efficiencies Corresponding to Average Ultimate Strengths Shown in Table 1

Nominal dimensions, in.			Efficiencies based on strength of unwelded plate, %*					
			3/16-in. welds			1/4-in. welds		
Over-all width, W	Length of weld, L	Marginal widths, (W-L)/2	Weld strip†	Marginal strips	Over-all	Weld strip†	Marginal strips	Over-all
9	3	3	62	89	79	58	87	76
8	3	2 1/2	62	86	76	58	85	74
7	3	2	62	83	73	58	82	71
6	3	1 1/2	62	81	71	58	76	66
6	6	0	62	..	62	58	..	58

* Based on average strength of 46,700 psi., shown for specimens 11-A, -B, and -C in Table 1.
† Determined for continuously welded specimens and assumed to be the same for all intermittent welds.

of each specimen was assumed to be made up of two parts: (1) the strength contributed by the strip normal to and in way of the welds, and (2), the strength of the marginal strips on each side of the welds. The strength and corresponding efficiency of these marginal strips in any case were obtained by subtracting the computed load-carrying capacity of the weld strip from the ultimate test load and comparing this difference with the ultimate load computed for an equal width of unwelded plate.

Table 1 indicates that all welded specimens, regardless of width, exhibited permanent elongations along the edges after fracture ranging from 8.5 to 14% in 2 in. Although such values are far from being indicative of a brittle-like behavior, it is probable that the notch effect or stress concentration at the ends of the intermittent welds influenced both the ultimate loads and the elongations exhibited by these specimens. This view is supported by the fact that the elongations measured on the edges of the unwelded specimens were almost double those measured on any of the welded specimens.

Failures in all the transverse welded specimens occurred by a ductile, shear-type plate fracture immediately adjacent to or within about $\frac{1}{2}$ in. of the edge of the welds. Figures 6 and 7 show typical examples. Necking down of the plate in way of the welds was always evident before fracture occurred. Although the elongations measured along the edges of the welded specimens were approximately the same, regardless of width, it is evident from Fig. 6 that the elongations of the intermittent welded specimens were not uniform across the width.

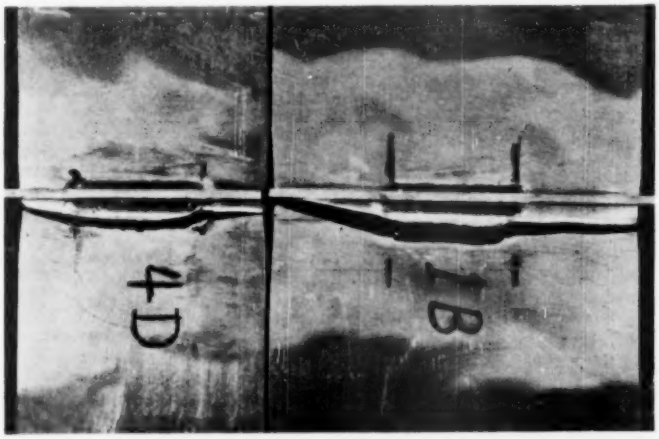


Fig. 6 Typical tensile failures of specimens representing intermittent transverse fillet welding

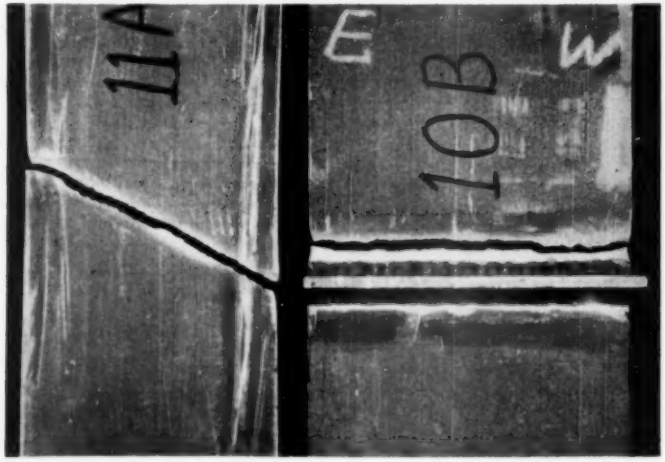


Fig. 7 Typical tensile failures of specimens representing continuous transverse fillet welding and unwelded plate

Figure 8 shows sections through the center of the $\frac{5}{16}$- and $\frac{1}{4}$-in. continuously welded specimens after fracture.

Longitudinal Shear Strength of Fillet Welds

Table 3 gives the results of the shear tests. Here again the actual sizes of weld were somewhat greater than specified. The yield and ultimate shear-strength values given, however, were based on the estimated actual throat area of the welds. These areas were obtained by multiplying the total length of weld effective in each half of the specimens (four $1\frac{1}{2}$-in. long welds) by one-half the average measured distance across the exposed face of the welds.

The yield strengths given in Table 3 were estimated as the points of first yielding on load-deformation curves of the type shown in Fig. 9. They were selected for comparative purposes only and bear no relation to the 0.2% offset-yield values selected for the tensile specimens having transverse fillet welds.

The yield and ultimate shear strengths given in Table 3 represent a surprisingly small range of values, considering the different sizes of weld and thicknesses of plate involved. The average yield values for each of the four groups ranged from only 4300 to 4500 psi., whereas the average

Fig. 8 Typical sections through transverse fillet welds after tensile failure of plates. (Top) $\frac{5}{16}$-in. fillets; (bottom) $\frac{1}{4}$-in. fillets

Table 3—Results of Alcoa Tests to Determine Longitudinal Shear Strength of Fillet Welds on 61S-T6 Plate

Specimen No.	Nominal size of weld, in.	Throat dimension, in. Nominal	Throat dimension, in. Measured*	Throat area, sq. in.†	First yielding‡ Load, lb.	First yielding‡ Stress, psi.	Ultimate strength Load, lb.	Ultimate strength Stress, psi.
1-A	3/16	0.133	0.24	1.44	6,000	4200	20,600	14,300
1-B	3/16	0.133	0.24	1.44	8,000	5600	21,650	15,000
1-C	3/16	0.133	0.26	1.56	6,000	3800	20,250	13,000
Av.						4500		14,100
2-A	1/4	0.177	0.28	1.68	6,000	3600	21,950	13,100
2-B	1/4	0.177	0.30	1.80	8,000	4400	25,250	14,000
2-C	1/4	0.177	0.28	1.68	8,000	4800	25,700	15,300
Av.						4300		14,100
3-A	5/16	0.265	0.32	1.92	8,000	4200	26,600	13,900
3-B	5/16	0.265	0.34	2.04	10,000	4900	28,800	14,100
3-C	5/16	0.265	0.33	1.98	8,000	4000	27,300	13,800
Av.						4400		13,900
4-A	1/2	0.354	0.40	2.40	10,000	4200	35,400	14,800
4-B	1/2	0.354	0.42	2.52	12,000	4800	36,400	14,400
4-C	1/2	0.354	0.44	2.64	10,000	3800	34,750	13,200
Av.						4300		14,100

* Assumed to be equal to one-half the distance across the exposed face of the fillets.
† Throat dimension times total length of four welds (6 in.).
‡ Estimated as point of first departure of load-deformation curves from initial straight-line portion.

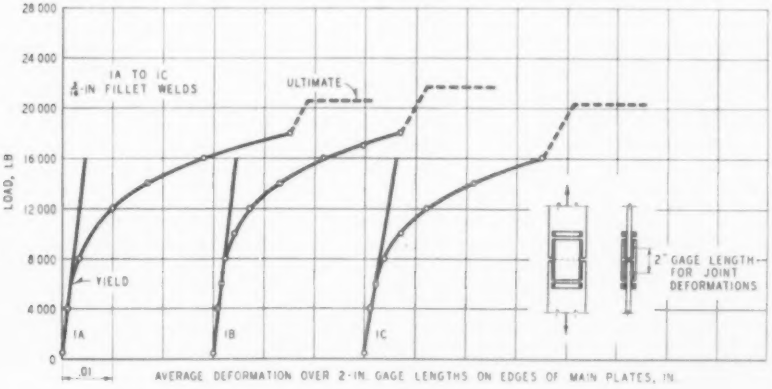


Fig. 9 Load-deformation curves for shear tests of fillet welds on 61S-T6 plates

ultimate strengths ranged from 13,900 to 14,100 psi. The maximum difference between any individual strength value and its corresponding average was only 1200 psi.

Similar tests of unshielded metal-arc fillet welds on specimens of somewhat different proportions have indicated slightly higher values of longitudinal shear strength.[1] The average ultimates for welds having nominal sizes of 1/4 to 5/16 in. and lengths of 1 1/2 to 6 in. ranged from 16,400 to 21,000 psi. It should be emphasized, however, that the lowest average of 16,400 psi. was obtained for 3/8-in. welds having a length of 1 1/2 in., or a length corresponding to that used in all of the present tests. The higher shear strengths for the metal-arc welds were obtained for lengths of 3 to 6 in. Since length of weld appears to be a significant factor in tests of this kind it can only be concluded

Fig. 10 Typical failures of fillet welds under longitudinal shear

from these comparisons that the average ultimate strengths of the metal-arc fillet welds were about 2400 psi. higher than the average observed here for argon-shielded tungsten-arc fillets of the same nominal size and length.

The average yield values indicated in Table 3 were approximately one-third the ultimate strengths. In the tests of the unshielded metal-arc welds previously referred to, the corresponding yield values were approximately one-half the ultimate strengths. Differences in plate proportions as well as effects of heat of welding by the two methods were undoubtedly involved.

All specimens of this series failed by shear of the welds. Figure 10 shows typical examples. Fractures occurred first in one pair of welds, followed a second or so later by fracture of a second pair, usually in the other half of the specimen. The action was not as sudden or violent as that obtained in the shear tests of the unshielded metal-arc fillet welds.

SUMMARY AND CONCLUSIONS

The results of the tests to show the effect of argon-shielded tungsten-arc fillet welds on the static tensile strength of aluminum alloy 61S-T6 plating may be summarized as follows:

1. Size of weld had a definite effect on plate strengths; the strengths obtained for the $^3/_{16}$-in. fillets being consistently higher than those observed for the $^1/_4$-in. size. The spacing of intermittent welds also had a significant effect on plate strengths; the greater the spacing, or the ratio of width of specimen to length of weld, the higher the strengths. These general observations, readily apparent in Fig. 5, emphasize the importance of keeping the size of fillet and the total length of weld to a minimum consistent with the requirements for shear strength and good welding.

2. The following tables show the average plate strengths and efficiencies obtained for specimens having continuous transverse welds and 3-in. intermittent welds on a 9-in. spacing. These values were the maximum and minimum observed in the tests and provide a quantitative basis for estimating possible heat effects in welded design.

3. All of the transverse welded specimens failed by ductile, shear-type plate fractures at or within about $^1/_2$ in. of the edge of the welds. The elongations measured on the edges of these specimens after failure ranged from 8.5 to 14% in 2 in., indicating that the discontinuities in section introduced by the welds did not limit seriously the capacity of the material to withstand plastic deformations.

The results of the tests to determine the longitudinal static shear strength of different sizes of argon-shielded tungsten-arc fillet welds on 61S-T6 plating may be summarized as follows:

1. Size of weld, ranging nominally from $^3/_{16}$ to $^1/_2$ in., did not have a significant effect on ultimate shear strengths, the average values for the four sizes investigated ranging from 13,900 to 14,100 psi.

2. First yielding of the welds in shear was observed at loads equal to about one-third of those which produced failure.

3. Both the first-yield characteristics and the ultimate shear strengths were somewhat lower than previously reported for specimens made by the unshielded, metal-arc process.[1]

	Average tensile stresses in plate, psi.				
	$^3/_{16}$-*in. welds*		$^1/_4$-*in. welds*		
Loading	*Continuous*	*9-in. centers*	*Continuous*	*9-in. centers*	*No welds*
First yield	13,500	30,000	7,000	30,000	36,000
0.2% offset	20,200	36,800	17,000	34,700	41,300
Ultimate	29,000	36,900	26,900	35,600	46,700

	Efficiencies, compared to unwelded plate, %			
	$^3/_{16}$-*in. welds*		$^1/_4$-*in. welds*	
Loading	*Continuous*	*9-in. centers*	*Continuous*	*9-in. centers*
First yield	37	83	19	83
0.2% offset	49	89	41	84
Ultimate	62	79	58	76

ACKNOWLEDGMENTS

The investigation described was initiated by Gibbs and Cox, Inc., of New York, N. Y., and the Marine Section of the Development Division, Aluminum Company of America, in connection with a study of the possibilities of welded aluminum alloy 61S-T6 in ship construction. All specimens were prepared by the Alcoa Process Development Laboratories. The tests were made at the Aluminum Research Laboratories.

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2. Hartmann, E. C., Holt, M., and Zamboky, A. N., "Static and Fatigue Tests of Arc-Welded Aluminum Alloy 61S-T Plate," *Ibid.*, **26** (3), Research Suppl., 129-s to 138-s (1947).
3. Alcoa Aluminum and Its Alloys, published by Aluminum Company of America, Pittsburgh, Pa., 1947.

Energy Distribution in Electric Welding

Increased speeds and current result in more efficient utilization of the welding energy available at the arc in both manual arc and submerged melt welding

by C. E. Jackson and A. E. Shrubsall

ABSTRACT

The energy distribution in welding with both coated electrodes and the submerged melt process is discussed. New data are presented, showing the utilization of energy in forming the weld nugget which constitutes the weld joint. The losses which are encountered for various welding techniques are considered. The discussion and results which are presented point to the following indications:

1. The energy utilized in melting the electrode for both coated electrodes and submerged melt welding for all current levels is approximately 15% of the total energy input.
2. The rate of melting the electrode for both coated electrodes and the submerged melt process, in general, increases with current.
3. Auxiliary energy, amounting to from 50 to 80% of the total energy input, is utilized in heating the plate, radiation, fusing Unionmelt or coating, convection, spatter and others.
4. The energy utilized in forming the weld nugget which constitutes the weld joint for both coated electrodes and Unionmelt welding ranges from approximately 20 to over 50% of the total energy input, the energy utilization increasing with current and speed of travel.

INTRODUCTION

IF ONE were a miniature, indestructible genie, and could carry suitable instruments into a welding zone, it might be possible to explore the distribution of the various potentials in this zone. It might also be possible to investigate the drastic changes which are encountered adjacent to the negative electrode, the cathode, or the positive electrode, the anode. Further information could also be gathered regarding the exact distribution of the voltages between the anode and the cathode. However, since such genii, at least such genii with the required intelligence, are quite unknown, it has been necessary to rely upon indirect methods for studying the distribution of the energy in the welding zone.

The following discussion is a result of a gradual accumulation of ideas having to do with the distribution of energy in the welding zone. It is realized that this presentation is not complete, although a review of these data, in light of current thoughts regarding the behavior in the welding zone, seems highly worth while.

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Presented at the Thirtieth Annual Meeting, A.W.S., Cleveland, Ohio, week of Oct. 17, 1949.

PREVIOUS RELATED INVESTIGATIONS

An early attempt was made by Alexander[1] to determine the distribution of the energy in the electric arc by the calorimetric method. The total energy input to the arc was measured by a specially calibrated watt-hour meter. The energy dissipated at the anode and at the cathode was estimated by the temperature rises of the electrodes. In Alexander's tests with iron, used for both anode and cathode, the energy developed at the surface of the anode was practically equal to that developed at the cathode. His tests also pointed out that various materials used as a coating on the electrodes may affect the distribution of the energy.

Various investigators have continued the study of the distribution of energy in electric arcs. Some scattered work has been directed toward analyzing the electric arc for welding. Research workers have been interested in, among other things, the distribution of potentials in the welding zone. Such studies have indicated that rather large voltage changes occur immediately adjacent to both the anode and cathode. These potential drops, occurring over a distance of not over a few tenths of a millimeter, have been referred to as the anode and cathode drops. The change in potential across the space between the electrodes has been commonly referred to as the space potential or plasma drop.

At the present time, there are several programs aimed at basic interpretation of the phenomena that occur in the welding zone. In one of these investigations at Johns Hopkins' by Kouwenhoven and Jones,[2] having to do with carbon arc phenomenon, a linear relationship has been shown between arc voltage and arc length for a 66-amp. arc between carbon and a moving steel tape. This curve, reproduced in Fig. 1, is a straight line over the region studied, with a slope of 32 v. per inch as the potential gradient in the arc stream for the conditions of the test. If this line is extended to the vertical axis corresponding to zero arc length, the intercept of 24 v. can be taken to indicate the order of the sum of the cathode and anode drops for this particular test condition.

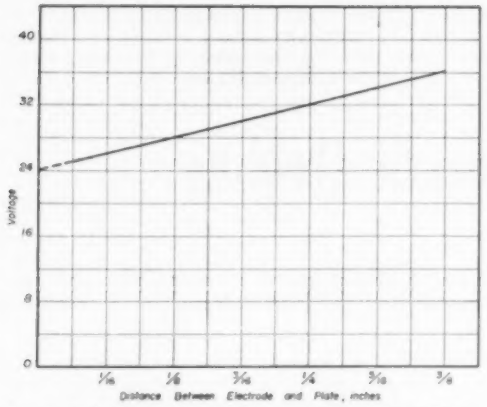

Fig. 1 Relation of distance between electrode and plate and voltage for carbon arc to steel tape using 66 amp. (After Kouwenhoven)

Winsor[3] has recently reported the relationship of voltage and arc length for an E-6012 type of electrode, using current levels from 120 to 240 amp. These data, shown in Fig. 2, are essentially linear for the lowest current density. It is noteworthy that the higher the current, the greater is the voltage required to maintain a given length of arc, and that for any given voltage, the arc length decreases with an increase in current. If the straight-line relationship which exists at 120-amp. welding current is extrapolated to zero arc length, an arc voltage of approximately 14 v. represents the sum of the anode and cathode voltages with a gradient of approximately 75 v. per inch. The potential gradient for higher currents is somewhat steeper.

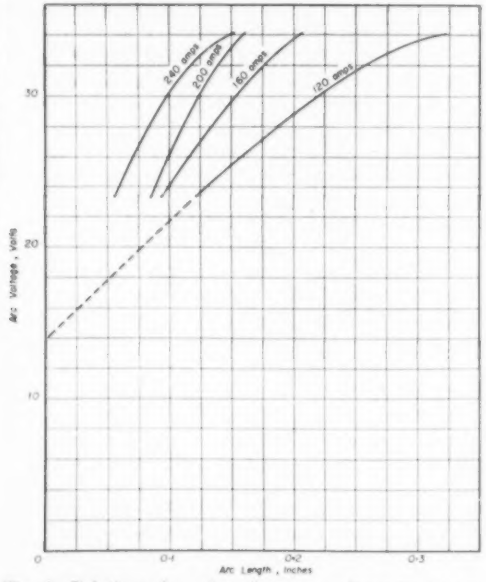

Fig. 2 Relation of arc length to arc voltage for 5/32-in. Type E-6010 coated electrodes. (After Winsor)

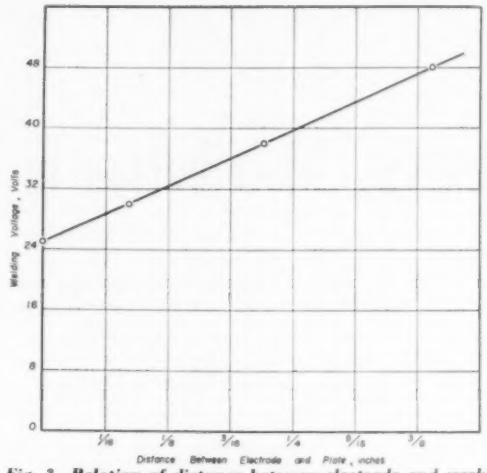

Fig. 3 Relation of distance between electrode and work and voltage for submerged melt welding (800 amp.) with AN-3 welding composition

NEW STUDIES OF ENERGY DISTRIBUTION

Radiographic Examination of Welding Zone

Extensive work has been carried out over the past years at the Union Carbide and Carbon Research Laboratories, Inc., using X-ray radiography for studying the welding zone in submerged melt welding. By setting the X-ray head to the side and at right angles to a stationary welding zone being deposited on a moving plate, pictures can be obtained with reasonable exposures. The vertical distance between the tip of the electrode and the top surface of the plate can be measured on the X-ray film using a pair of caliphers and a rule. In those cases in which the welding technique is such that a shallow crater is formed more or less at the level of the surface of the plate, these measurements represent the actual distance between the tip of the electrode and the plate. Considerable error, of course, can exist for those welding techniques in which the surface of the crater is depressed below the surface of the plate. For this reason, the X-ray technique is applicable only to beads on the surface of a plate or to completely filled grooves. A review of the data indicates that

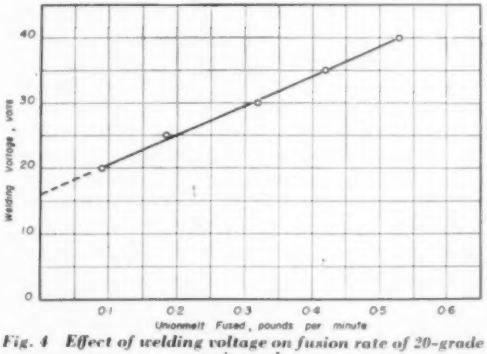

Fig. 4 Effect of welding voltage on fusion rate of 20-grade unionmelt

1. For a given welding current and 20-grade Unionmelt* composition, the distance between the tip of the electrode and the plate increases with voltage.

2. For a given welding current and 20-grade Unionmelt composition, the distance between the tip of the electrode and the plate decreases slightly with an increase in speed of travel.

3. For a given welding technique and 20-grade Unionmelt composition, the distance between the tip of the electrode and the plate decreases slightly with a decrease in the diameter of the electrode.

Ostapenko and Medovar[1] have recently reported studies of the welding zone in submerged melt welding by X-ray radiography. From the results of their investigation, the relationship, shown in Fig. 3, between voltage and distance between the electrode and plate, can be shown. Here again, a linear relationship exists, and in accordance with the zero intercept, the sum of the anode and cathode drops is approximately 25 v., with a potential gradient of 58 v. per inch in the fused melt. Further X-ray radiographic experiments reported by Ostapenko and Medovar show that the welding composition will influence the distance between the electrode and plate. For example, using 800 amp., 40 v. and 16.4 in. per minute travel with AN-3 material with particle size 8 by 26, the distance between the electrode and plate was 9 mm. (0.35 in.), while with the same technique and a second material, OSTs-45, with particle size 8 by 20, the distance was 3 mm. (0.12) in.).

* Registered trademark, The Linde Air Products Co., for its submerged melt welding composition and apparatus.

No direct data are presented showing the effect of increasing rod diameter in the submerged melt process, but from one test reported by Ostapenko, with an electrode inclined at 45°, thus providing a larger cross-sectional area at the arc to carry the current of 800 amp., a welding zone drop of 34 v. was obtained for an arc length of 8 mm. When the electrode was vertical, the cross-sectional area at the arc was less, and the drop was 44 v. for a distance of 8 mm. between the electrode and plate.

Effect of Voltage on Quantity of Unionmelt Fused

Instead of measuring arc lengths or using X-ray radiographic techniques, a similar type of relationship has been shown by determination of the effect of welding voltage on the Unionmelt fused per minute. If the quantity of granular material fused per minute in the submerged melt process is measured for a given current over an increasing range of voltages, a gradual increase in the quantity of granular material fused per minute is noted. For example, at 600 amp., direct current, electrode positive, with 20-grade Unionmelt, the following results were obtained:

Voltage	Unionmelt fused, lb./min.
20	0.09
25	0.18
30	0.30
35	0.42
40	0.53

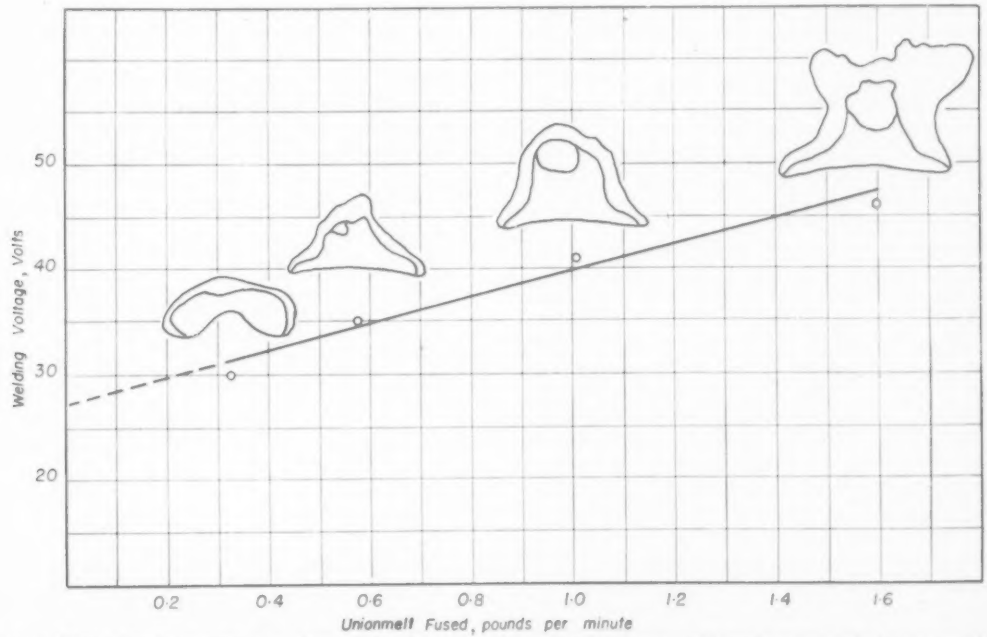

Fig. 5 Effect of welding voltage on shape of fused cross section and fusion rate of 20-grade unionmelt for 1-in. welds made using 1550-amp. alternating current, 11 in. per minute travel

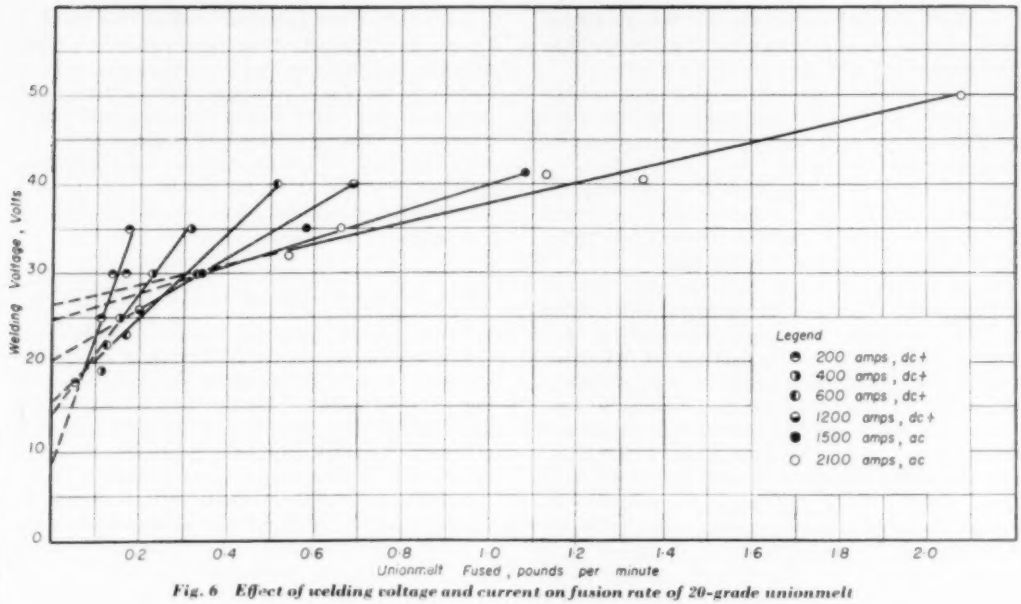

Fig. 6 Effect of welding voltage and current on fusion rate of 20-grade unionmelt

Plotting these data, a straight-line relationship (Fig. 4) is obtained. That such a relationship between voltage and Unionmelt fused per minute is linear, indicates that an increase in the over-all voltage mainly affects the potential existing in the space between the anode and cathode.

It is assumed that as the quantity of Unionmelt fused per minute approaches zero, the space or plasma potential would also approach zero; the intercept on the vertical ordinate, therefore, can logically be assumed to be the sum of the anode and cathode potentials. Thus, extrapolation of the linear portion of Fig. 4 to zero melt fused per minute gives a sum of the anode and cathode potentials of 16 v. for a welding current of 600 amp.

In similar tests performed at 1550 amp. (Fig. 5), the zero intercept occurs at a voltage of approximately 27 v. Outlines are included in Fig. 5 which indicate the shape of the cross section of the fused Unionmelt produced during the welding operation. It is readily recognized from a welding standpoint that the intermediate voltages of 35 and 41 give smooth weld surfaces with the minimum consumption of Unionmelt. Further data from other tests, which relate voltage, current and fusion rate of 20-grade Unionmelt, indicate that the zero intercept increases as the current in the welding zone is increased (Fig. 6).

It is interesting to note that for currents of 400 amp. and above, the minimum voltage at which a weld could be made was approximately 5 v. above the anode and cathode intercept. If the voltage at which zero Unionmelt is fused is indicative of the anode and cathode voltage, then as the current increases, the sum of the anode and cathode potentials increases (Fig. 7). If the increase in anode and cathode potential were in accordance with Ohm's Law ($E = IR$), then the relationship would increase linearly as I. The relation, however, based on the data available is not linear. Hausner[5] points out that polarization effects and departure from Ohm's Law are evidence of ionic or electrolytic conduction.

Since the quantity of Unionmelt fused per unit time is related linearly to the voltage across the welding zone, and since an increase in normal voltages does not materially affect the melting rate of the electrode or the

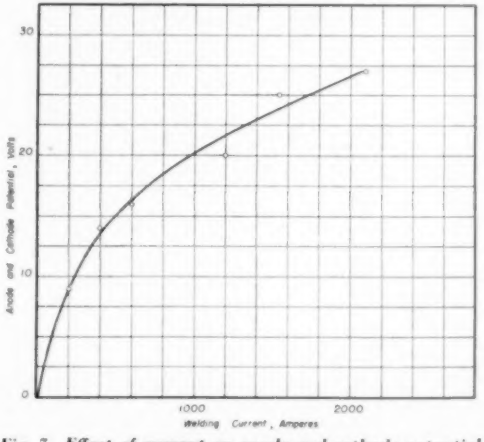

Fig. 7 Effect of current on anode and cathode potential for 20-grade unionmelt

area of the nugget, it is possible to measure the energy required to fuse the granular material in the submerged melt process. For example, by increasing the welding voltage from 30 to 46 v., an increase of 1.27 lb. of 20-grade Unionmelt fused per minute was obtained at 1550 amp. From the 16-v. change at 1550 amp., the power used in fusing 1.27 lb. of Unionmelt per minute can be calculated as 24.8 kw. Since 60 times 1.27 lb. of Unionmelt was fused per hour, the energy requirement will be 24.8 / (60 × 1.27) or 0.32 kw.-hr. per pound of Unionmelt fused. The power required to fuse a pound of Unionmelt with various techniques will change; for example, with 600 amp. and 20 in. per minute travel, 0.45 kw.-hr. was used per pound and at 2100 amp., 6 in. per minute travel, 0.37 kw.-hr. was used to fuse 1 lb. of 20-grade Unionmelt. It is expected that a relationship can be shown between current, speed of travel and the energy required to fuse 1 lb. of Unionmelt, although from these results it appears that for 20-grade Unionmelt an average of slightly less than 0.4 kw.-hr. is required to fuse 1 lb. Usually, the voltage employed in a proper welding technique is such that the melting rates of the Unionmelt and electrode are roughly equal. High voltages, which are sometimes necessary in order to obtain flat top surfaces, will increase the melt consumption.

Little information is available regarding the effect of type of current, whether direct, with electrode either positive or negative, or alternating, on the sum of the anode and cathode voltages in submerged melt welding. As shown in Fig. 8, there is a rather minor effect from the use of alternating current or direct current, straight or reverse polarity for one sample of 20-grade Unionmelt. At 600-amp. current for this sample, the sum of the anode and cathode voltages obtained by extrapolation is in the order of 15 to 16 v. The type of current may be important at higher currents.

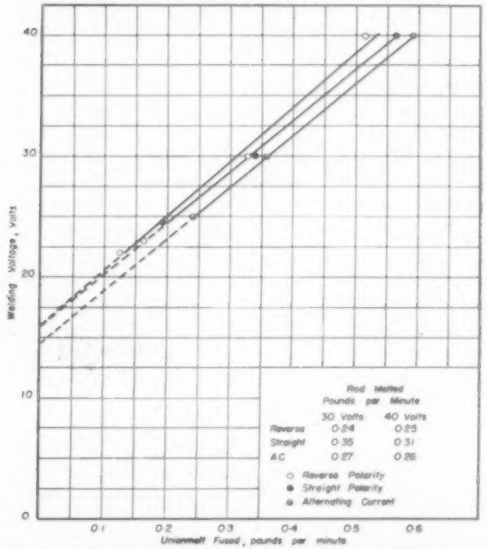

Fig. 8 Effect of welding voltage at 600 amp. on fusion rate of 20-grade unionmelt

Ratio of Anode and Cathode Potentials

In the submerged melt process, it is rather difficult to determine the ratio of the anode and cathode potentials, since the usual practice of making probe measurements cannot be applied. Some indication may be obtained by comparing the melting rate of the electrode, using first straight, and then reverse polarity. For example, in one series of tests with a special Unionmelt operating at 600 amp. under identical conditions except for the polarity of the electrode, the melting rate of the electrode with straight polarity was 0.44 lb. per minute, and for electrode with positive or reversed polarity, was 0.35 lb. per minute. Since the energy liberated at the electrode is largely controlled by the potential drop at the interface between the fused Unionmelt and the electrode, probably over a thickness in the order of 0.01 in., the ratio of the anode to the cathode potential may be considered to be approximately the ratio of the melting rates. In the above series of tests with a special Unionmelt, the sum of the anode and cathode potentials, as measured by the fused Unionmelt intercept, was 18 v. The melting rates of the electrode for reverse and straight polarity were in the ratio of 35:44; it may be assumed that the anode and cathode drops are in the same ratio. Hence, at 600-amp. current, with this special grade of material, the anode drop was (35 × 18)/(35 + 44) or 8 v., and the cathode drop was 10 v.

Other tests with other Unionmelt materials have indicated little or no difference in the melting rate, even with change in polarity. Apparently, the distribution of the anode and cathode potentials is primarily dependent upon the particular material which is used and the exact conditions of polarization which exist. For example, in welds using 20-grade Unionmelt at 1200 amp., 40 v. and 12.5 in. per minute travel, the rod consumed for reverse polarity was 0.61 lb. per minute, while for

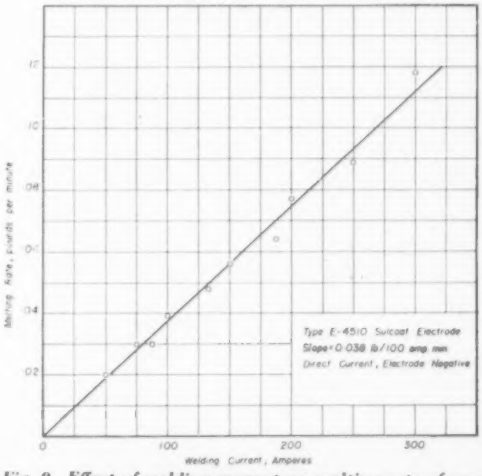
Melting Rate, pounds per minute
Welding Current, Amperes
Type E-4510 Suicoat Electrode
Slope=0.038 lb/100 amp min
Direct Current, Electrode Negative

Fig. 9 Effect of welding current on melting rate of cor-wire in a typical E-4510 type electrode. (Private communication)

straight polarity it was 0.59 lb. per minute. This would indicate that the anode and cathode potentials are approximately equal.

Effect of Current on Melting Rate of Electrode

Recently Martin, Rieppel and Voldrich[6, 7] have reported the results of an extensive investigation concerned with the melting characteristics of steel welding electrodes. Although all of their tests were restricted to $^{3}/_{16}$-in. diameter electrodes, they include results using bare and coated electrodes. At normal manual welding currents, the melting rates vary directly with the current, but at high currents, the slope of the current-melting rate relationship tends to increase as the current density increases. The pronounced difference in operating characteristics of electrodes with different coatings is attributed by these investigators principally to the direct influence of the coating characteristics (factors such as ionization potentials, ion supply, etc.), and of metal-transfer characteristics (surface tension, deoxidation, chemical reaction, etc.).

Extensive data are available in the commercial literature regarding the melting rates of various brands of coated electrodes with diameters of $^{1}/_{8}$ to $^{5}/_{16}$ in. Usually, these data are reported in arc time per inch or foot of rod melted. If these data are recalculated so that the melting rate is given in pounds of core wire per minute, it is possible to compare the effects of current on melting rate for various electrodes. For example, in Figs. 9 to 14 are shown results for E-4510, E-6012 and E-6020 with direct-current electrode negative, E-6010 and E-6015 with direct-current electrode positive, and E-6013 with alternating current. In all cases, a straight

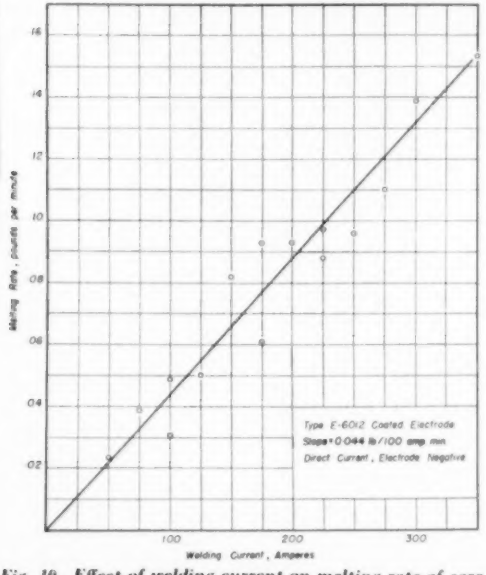
Melting Rate, pounds per minute
Welding Current, Amperes
Type E-6012 Coated Electrode
Slope = 0.044 lb/100 amp min
Direct Current, Electrode Negative

Fig. 10 Effect of welding current on melting rate of core wire in a typical E-6012 type electrode. (Data from commercial literature)

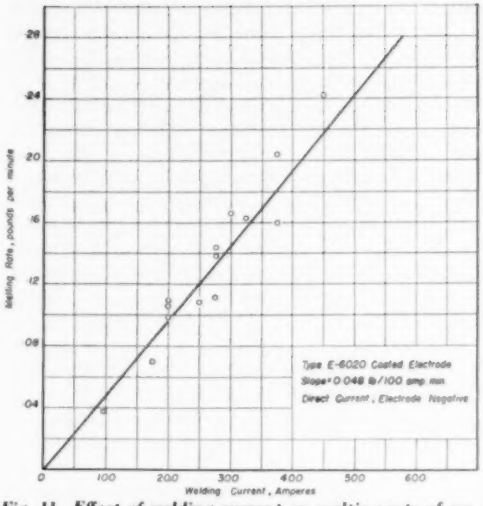
Melting Rate, pounds per minute
Welding Current, Amperes
Type E-6020 Coated Electrode
Slope = 0.048 lb/100 amp min
Direct Current, Electrode Negative

Fig. 11 Effect of welding current on melting rate of core wire in a typical E-6020 type electrode. (Data from commercial literature)

line represents the data fairly well, although considerable scatter is shown in some of the results, particularly in E-6012 type of electrode. It is to be noted that in some cases, data have been plotted in which the currents are both below and above the normal welding range. From these results, E-6020 shows the highest melting rate, followed by E-6010, E-6012, E-6013, E-4510 and E-6015. The results indicate that the E-6020 type has approximately 1.41 times the melting rate of that for the E-6015 type of electrode. Since the melting rate of the electrode is governed by the current and voltage drop at the electrode, it is logical to assume that for any given current, the anode or cathode drop (depending upon which polarity is used) at the electrode varies in the same order as the melting rate. Hence, it can be assumed that the cathode drop for an E-6020 type of electrode, with electrode negative, is higher than the anode drop for an E-6015 electrode, with electrode positive.

In the submerged melt process, the melting rate of the electrode also increases as the current increases, although, as seen in Fig. 15, the slope of the current-melting rate curve has a slight tendency to increase as the current increases. Here again, changes in the anode or cathode voltages produced by changes in Unionmelt composition, or changes in voltage level, speed of travel or in rod preheat will influence the dispersion of results. Additional data covering a higher range of currents may also show a change in slope with increasing current for coated electrodes.

In welding with coated electrodes under abnormal conditions, some loss is encountered during the deposition of the electrode by spatter. In modern electrodes under normal welding conditions, this loss is usually not over 5% of the metal being transferred. No spatter loss is encountered during transfer of the molten weld metal in the submerged melt process.

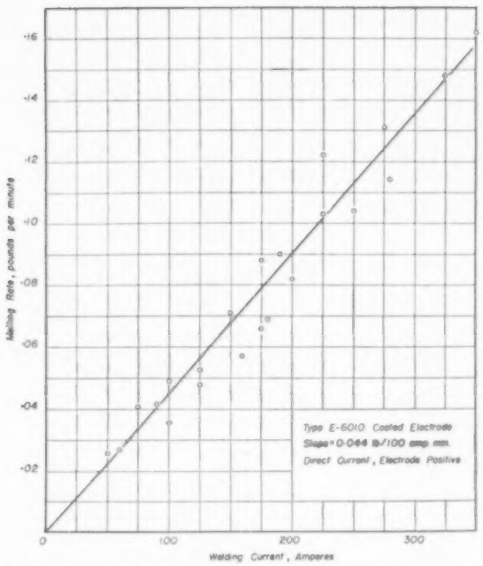
Melting Rate, pounds per minute
Welding Current, Amperes
Type E-6010 Coated Electrode
Slope=0.044 lb/100 amp min.
Direct Current, Electrode Positive

Fig. 12 Effect of welding current on melting rate of core wire in a typical E-6010 type electrode. (Data from commercial literature)

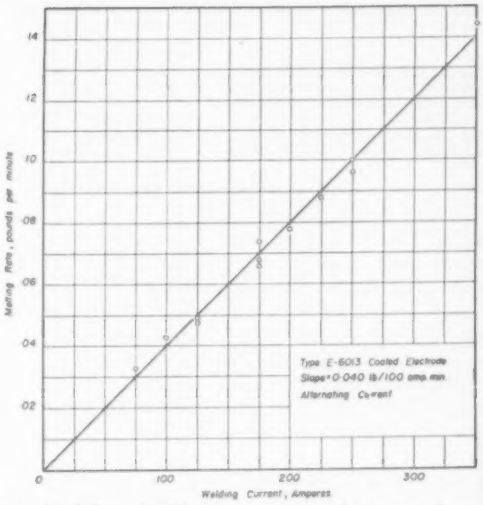

Fig. 14 Effect of welding current on melting rate of core wire in a typical E-6013 type electrode. (Data from commercial literature)

Heat Balance in Welding Zone

Now that some approximation has been made to the many apparently definite relationships that exist in electric welding, it is possible to utilize them to make estimates of the energy balance in typical welds. We will first use examples of submerged melt welding, with the following conditions for the first weld. A surface bead weld was deposited on a $^1/_2$-in. thick mild-steel plate using 600 amp., DCRP, 30 v., and 20 in. per minute travel. The electrode (Type, Oxweld No. 36) was $^3/_{16}$ in. in diameter; 20-grade Unionmelt (20 by D) was used. The melting rate of the electrode was found to be 0.292 lb. per minute with a Unionmelt consumption of 0.304 lb. per minute. The area of the nugget was 0.158 sq. in. with a deposit to base metal ratio of 0.49. The heat required for fusing the weld metal in the welding zone can be calculated, assuming that 151,000 calories* is required to melt 1 lb. of weld metal. In a like manner, the heat required to fuse the base metal can be computed. From previous calculations given earlier in this paper, the energy required to fuse the Unionmelt composition consumed in the operation at 600 amp. was determined as 0.45 kw.-hr./lb. The total heat input, H, per minute can be calculated as follows:

$$H = 0.24\,IET$$
$$= 0.24 \times 600 \times 30 \times 60$$
$$= 259{,}200 \text{ calories/min.}$$

where

I = current, amp.
E = voltage
T = time, sec.

This heat energy was distributed as shown in the following table.

A second weld was made joining two plates of mild steel, 2 in. thick, using 2100 amp., 41 v. and 6 in. per

* This is obtained if we assume a specific heat of 0.17 calorie per gram for the weld metal over the range of temperature from room to 1600° C. and 65 calories as the heat of fusion for iron. This calculation is further substantiated by data presented by K. K. Kelly, Contributions to the Data on Theoretical Metallurgy, Bureau of Mines Bulletin No. 371.

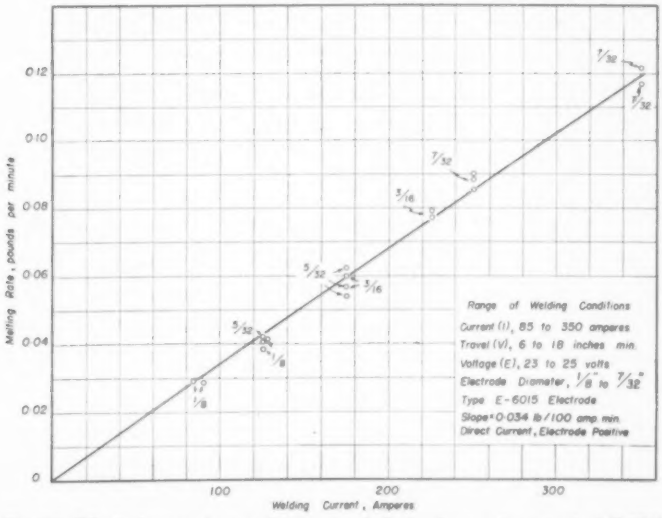
Melting Rate, pounds per minute
Welding Current, Amperes
Range of Welding Conditions
Current (I), 85 to 350 amperes
Travel (V), 6 to 18 inches min.
Voltage (E), 23 to 25 volts
Electrode Diameter, 1/8" to 7/32"
Type E-6015 Electrode
Slope=0.034 lb/100 amp min.
Direct Current, Electrode Positive

Fig. 13 Effect of current on melting rate of electrode core in a typical E-6015 type electrode. (Author's data)

	Calories	Total energy, %
Heat utilized in melting electrode	44,100	17
Heat utilized in melting base metal	89,390	34
Total heat utilized in forming weld nugget	133,490	51
Heat required to fuse Unionmelt	118,200	45
Heat loss in heating plate, radiation, etc.	7,510	4

minute travel. The electrode (Type, Oxweld No. 36) was $^3/_8$ in. in diameter, with 20-grade (20 by D) Unionmelt. The melting rate of the electrode was 1.20 lb. per minute with a Unionmelt fusion rate of 1.35 lb. per minute. The cross-section area of the weld nugget was 2.53 sq. in., with a deposit-to-base-metal ratio of 0.42.

The total heat input per minute can be calculated as $0.24 \times 2100 \times 41 \times 60$ or 1,239,840 calories per minute. This heat was distributed as follows:

	Calories	Total energy, %
Heat utilized in melting electrode	181,200	14
Heat utilized in melting base metal	460,550	38
Total heat utilized in melting weld nugget	641,750	52
Heat required to fuse Unionmelt	428,070	34
Heat loss in heating plate, radiation, etc.	170,030	14

Similar analyses of the data obtained for coated electrodes may be made. For example, a weld deposit made using a $^7/_{32}$-in. diameter E-6015 electrode with 350 amp. at 25 v. and 6 in. per minute travel, resulted in a melting rate of electrode of 10.9 in. per minute, or, based on the core wire, 0.117 lb. per minute. Measurement of the nugget area showed a cross-section area of 0.155 sq. in., with a deposit to base metal ratio of 0.91.

The total input per minute was $0.24 \times 350 \times 25 \times 60$ or 126,000 calories.

The heat utilized in melting the electrode core and base metal may be calculated.

	Calories	Total energy, %
Heat required to melt electrode	17,670	14
Heat required to melt base metal	19,930	16
Total heat utilized in melting weld nugget	37,600	30
Heat loss in heating plate, fusing coating, radiation, convection, etc.	88,400	70

Additional tests have been made using other types of electrodes, such as E-6010, E-6012 and E-6020, as well as other tests with Unionmelt. The results of these tests are given in Table 1. From these results it appears that the utilization of the energy in electric welding in general becomes more efficient as the current is increased. The heat required to form the weld nugget, consisting of the deposited metal and base metal which become molten, may be expressed as a percentage of the

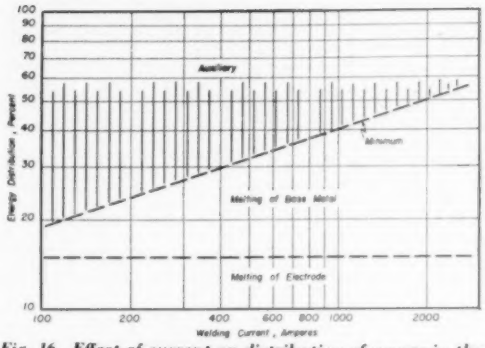

Fig. 16 Effect of current on distribution of energy in the formation of the weld nugget with unionmelt and coated electrodes

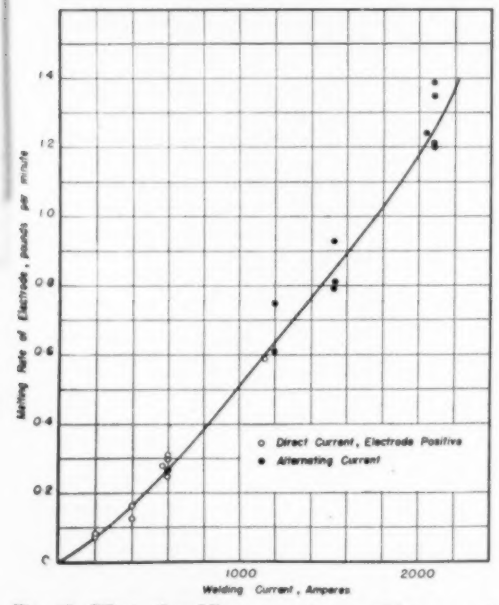
Melting Rate of Electrode, pounds per minute
Welding Current, Amperes
Direct Current, Electrode Positive
Alternating Current

Fig. 15 Effect of welding current on melting rate of electrode using 20-grade unionmelt

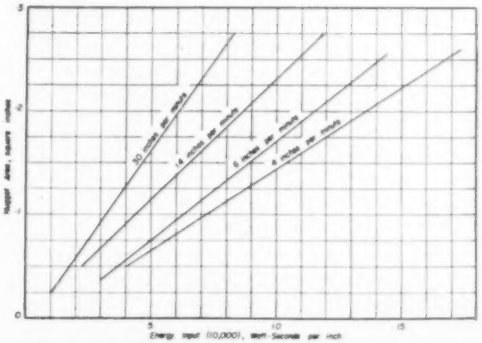

Fig. 17 Relation of nugget area to energy input

Table 1—Distribution of Energy in Typical Weld Tests

Weld No.	Process	Plate Thickness In.	Electrode Type	Electrode Diam. In.	Amps I	Volts E	Speed In./min	Polarity	Melting Rate lb./min. Elec.	Melting Rate lb./min. Melt	Nugget Area Sq. In.	Total Input Cal./Min.	Heat Distribution: Useful Energy: Electrode Cal.	Electrode %	Useful Energy: Base Metal Cal.	Base Metal %	Useful Energy: Total %	Auxiliary Input: Melt Cal.	Melt %	Auxiliary Input: Balance Cal.	Balance %
B-547	Coated	.5	E-6035	5/32	175	26	6	DCR	0.097	–	0.061	65,520	8,610	13	7,400	11	24	–	–	49,510	76
B-528	"	.5	E-6035	1/8	128	24	6	"	0.044	–	0.044	44,230	6,660	15	4,510	10	25	–	–	33,060	75
B-534	"	.5	E-6035	7/32	230	25	6	"	0.117	–	0.135	126,000	17,670	14	19,930	16	30	–	–	88,400	70
B-531	"	.5	E-6035	5/16	175	24	6	"	0.080	–	0.091	60,480	9,060	15	8,640	14	29	–	–	42,740	71
B-548	"	.5	E-6035	5/32	175	24	6	"	0.097	–	0.063	60,480	8,610	12	7,530	11	23	–	–	44,320	77
75-23	Coated	1.0	E-6020	1/4	275	29	6	DCR	0.124	–	0.170	114,840	18,720	16	24,460	21	37	–	–	71,650	63
B-471	"	.5	E-6010	3/16	170	25	6	"	0.071	–	0.095	61,200	10,720	17	13,950	23	40	–	–	36,530	60
B-472	"	.5	E-6012	3/16	170	25	6	"	0.086	–	0.076	61,200	7,970	13	8,620	14	27	–	–	42,610	70
B-473	"	.5	E-6010	3/16	170	25	6	"	0.077	–	0.091	61,200	11,630	19	10,910	18	37	–	–	38,660	63
B-474	"	.5	E-6013	3/16	175	25	6	"	0.088	–	0.099	63,000	8,680	14	5,530	8	22	–	–	48,990	78
B-475	Coated	.5	25-20	3/16	160	25	6	DCR	0.087	–	0.068	57,600	13,140	23	7,100	12	35	–	–	37,360	65
B-476	"	.5	16 Cr	3/16	195	29	6	"	0.091	–	0.090	70,200	13,740	20	9,230	13	33	–	–	47,290	67
B-477	"	.5	E-6020	3/16	210	29	6	"	0.096	–	0.089	75,880	11,480	15	12,230	16	31	–	–	51,170	69
B-478	"	.5	E-6012	3/16	200	26	6	DCR	0.095	–	0.078	74,880	11,320	15	8,190	11	26	–	–	55,400	74
B-479	"	.5	E-6010	3/16	175	26	6	DCR	0.071	–	0.083	65,520	10,720	16	10,870	17	33	–	–	43,930	67
B-42	Un	.5	36	1/8	200	30	6	DCR	0.099	0.132	0.103	86,400	14,950	17	11,280	13	30	54,430	63	5,690	7
B-72	"	.5	36	3/16	600	30	20	"	0.312	0.278	0.147	259,200	47,110	18	77,160	30	48	128,090	49	26,840	10
B-105	"	.5	36	3/16	600	30	20	"	0.292	0.304	0.158	259,200	44,100	17	69,390	26	43	118,200	46	7,510	4
B-310	"	.5	36	3/16	600	30	20	"	0.254	0.293	0.146	259,200	38,350	15	85,160	33	48	113,140	44	22,550	8
B-552	"	.5	36	3/16	600	30	20	"	0.264	0.305	0.131	259,200	39,880	15	70,980	27	42	141,410	55	6,730	3
B-111	"	.5	36	3/16	600	30	10	DCR	0.333	0.331	0.224	259,200	30,280	20	46,390	17	37	129,600	50	34,920	13
B-112	"	.5	36	3/16	600	30	30	"	0.248	0.265	0.112	259,200	40,670	16	98,900	38	54	85,540	33	34,090	13
B-119	"	.5	36	3/16	600	30	40	"	0.274	0.259	0.088	259,200	41,370	16	107,210	41	57	80,350	32	30,260	11
B-694	"	.5	36	3/16	200	25	6	"	0.082	0.109	0.092	86,400	12,400	14	10,870	13	27	44,830	52	18,300	21
B-943	"	.5	36	3/16	600	30	60	"	0.289	0.185	0.051	259,200	43,640	17	115,880	45	62	74,540	29	24,800	9

* Heat utilized in forming weld nugget or weld joint.

total input, and is at least partially related to the current used in the welding operation. This is shown in Fig. 16 for the submerged melt process and for welds made using coated electrodes. Regardless of the type of welding process used, the energy utilized in melting the electrode with normal current densities is approximately 15% of the total energy. The energy utilized in fusing base metal which, together with the molten metal from the electrode, forms the weld nugget, is not nearly so constant. A minimum value is shown in Fig. 16 for the energy used in melting of base metal. This energy increases from approximately 5 to 35% as the current is increased from 100 to 2000 amp. The energy which is used in melting the base metal forming part of the weld nugget is increased above this minimum by an increase in speed of travel, or a decrease in the quantity of base metal which cools the weld nugget, thus resulting in excess penetration. This area of energy distribution is shown in Fig. 16 as vertical lines. The difference between the energy utilized for forming the weld nugget and the total energy is made up by the losses due to radiation, conduction, convection and/or fusion of Unionmelt or of electrode coating. As shown in Table 1, the particular brand of E-6010 coated electrode used in these tests shows a high efficiency compared with that obtained for other types of coated electrodes. It is not known whether this is a characteristic common to all E-6010 types of electrode.

Factors Controlling Nugget Area

In any study of the energy distribution in electric welding, some indication of the total quantity of metal which is fused is important. It is this fused metal which, when properly positioned by the welding process, must necessarily form the weld joint. It is well recognized that the nugget area (area of cross section of weld), including both the molten metal transferred from the electrode and the quantity of base metal which is fused, increases as the welding current is increased. In a like manner, as the speed of travel is increased for a given current, the nugget area will decrease. It has

Table 1—Distribution of Energy in Typical Weld Tests (*Contd.*)

Weld No.	Process	Plate Thickness In.	Electrode Type	Electrode Diam. In.	Amps I	Volts E	Speed In./min	Polarity	Melting Rate lb./min. Elec.	Melting Rate lb./min. Melt	Nugget Area Sq. In.	Total Input Cal./Min.	Heat Distribution: Useful Energy: Electrode Cal.	Electrode %	Useful Energy: Base Metal Cal.	Base Metal %	Useful Energy: Total %	Auxiliary Input: Melt Cal.	Melt %	Auxiliary Input: Balance Cal.	Balance %
1A384	UN	.75	36	1/4	1300	40	11.6	AC	0.670	0.870	0.630	748,800	105,000	14	235,000	31	45	300,000	40	108,800	15
16273-1	"	2.0	36	3/8	2100	41	6	"	1.20	1.20	2.23	1,239,840	181,200	14	460,550	38	52	428,070	34	170,030	14
15093	"	1.0	36	1/16	125	23	4	DCR	0.062	0.067	0.042	41,460	6,340	15	750	2	17	23,160	55	11,100	27
15084	"	1.0	36	1/16	170	28	6	"	0.061	0.128	0.052	68,540	9,210	14	4,380	6	20	44,260	65	10,720	15
14979-1	"	1.0	36	3/16	410	26	14	"	0.159	0.210	0.091	153,300	24,000	16	29,900	19	35	72,580	47	27,030	18
15004-2	"	1.0	36	3/16	550	30	20	DCR	0.234	0.232	0.120	237,600	35,330	15	66,140	28	43	80,180	34	55,980	23
14973-3	"	1.0	36	1/4	800	26	27.4	"	0.304	0.282	0.130	299,520	45,900	15	106,440	35	52	97,110	33	51,860	17
17407-1	"	.5	36	1/4	890	28	16	AC	0.404	0.286	0.296	342,720	61,000	17	135,050	40	57	98,840	29	47,820	14
17410-1	"	.75	36	1/4	1250	40	12.5	"	0.673	0.784	0.452	691,200	101,620	15	215,480	31	46	264,060	38	110,060	16
16773-2	"	2.0	36	3/8	2100	41	6	"	1.23	1.13	2.41	1,239,840	189,730	15	429,970	34	49	390,530	32	229,610	19
16776-1	"	2.0	36	3/8	2100	41	6	AC	1.20	1.33	2.43	1,239,840	181,200	15	434,080	35	50	466,560	38	157,200	12
16776-2	"	2.0	36	3/8	2100	41	6	"	1.19	1.52	2.48	1,239,840	179,690	15	449,380	36	51	525,310	43	85,460	7
16776-3	"	2.0	36	3/8	2100	41	6	"	1.21	1.44	2.60	1,239,840	182,710	15	476,860	37	52	497,660	40	82,610	8
16436-7	"	14 ga.	36	1/8	450	23	150	DCR	0.215	–	0.014	149,040	32,460	22	53,760	36	58	31,680	21	31,140	21
17624-1	"	1.0	36	5/16	1550	44	11	AC	0.615	0.885	1.02	915,120	123,080	14	352,380	38	52	305,860	33	134,820	15
B-702	"	.5	36	3/16	600	30	10	DCR	0.299	0.321	0.244	259,200	45,190	17	66,660	26	43	110,980	43	36,670	14
B-695	"	.5	36	3/32	200	30	6	"	0.088	0.135	0.030	86,400	13,290	15	6,950	8	23	46,660	54	19,510	23
B-700	"	.5	36	1/8	400	30	20	"	0.123	0.224	0.092	172,800	18,570	11	59,200	34	45	77,410	45	17,610	10

* Heat utilized in forming weld nugget or weld joint.

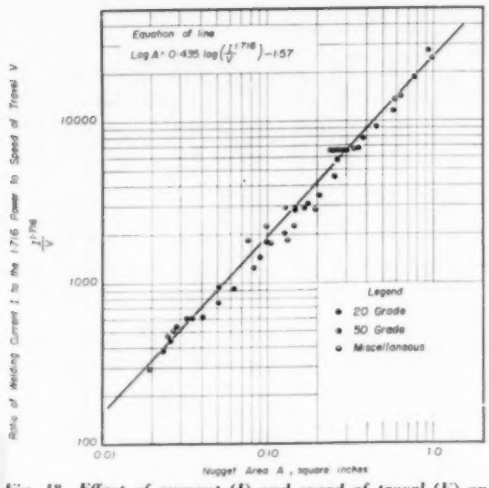

Fig. 18 Effect of current (I) and speed of travel (V) on nugget area (A) for unionmelt welding

been shown[8] for many of the standard Unionmelts that a family of curves can be drawn (Fig. 17) from which it is possible to predict the nugget area for any given welding technique. This family of curves suggests the possibility of setting up a single general equation for calculating nugget area from welding technique. The nugget area appears to be controlled mainly by the current and speed of travel used, and for the data available is related directly to the 1.716 power of the current and inversely to the first power of the speed of travel. As shown in Fig. 18, this relationship is linear when plotted on logarithmic paper. The data shown in this figure are based on tests using the submerged melt process covering a wide range of currents from 200 to 2100 amp. and speed of welding ranging from 5 to 60 in. per minute. The area of the nugget appears to be relatively unaffected by normal changes in welding voltage. Mathematically, an equation of the straight line representing the data in Fig. 18 can be expressed as

$$\text{Log } A = 0.435 \log ((I/V)^{1.716}) - 1.57$$

where

A = nugget area, sq. in.
I = current, amp.
V = volts.

In order to simplify the calculations required in solving this equation, the alignment chart shown in Fig. 19 has been constructed.

From published data[9] showing nugget areas obtained with coated electrodes, nugget areas slightly larger than those for Unionmelt at a given energy level were obtained for an E-6010 type of electrode, and slightly smaller nugget areas at a given energy level, especially at the higher currents, were obtained for an E-6020 type of electrode.

CONCLUSIONS

The discussion and results which have been presented point to the following indications regarding the energy distribution in electric welding.

1. The energy utilized in forming the weld nugget for both coated electrodes and submerged melt welding ranges from approximately 20 to over 50% of the total energy input, the energy utilized increasing with current and speed of travel. The balance of the total energy input may be utilized in heating the plate, radiation, fusing Unionmelt, or coating and other auxiliary effects.

2. The energy utilized in melting the electrode for both coated electrode and Unionmelt welding for all current levels is approximately 15% of the total energy input.

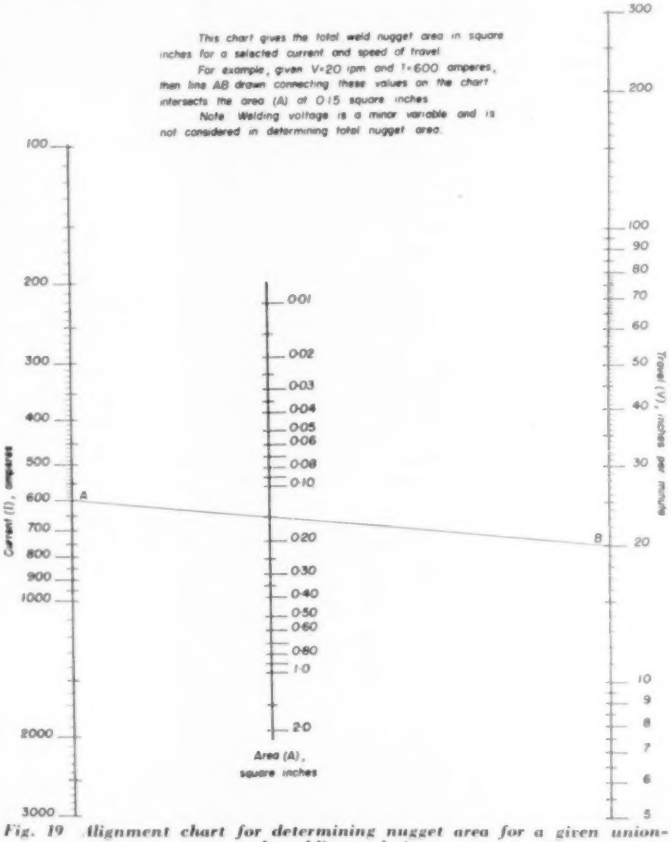

Fig. 19 Alignment chart for determining nugget area for a given unionmelt welding technique

3. The utilization of energy in forming the weld nugget for both coated electrodes and submerged melt welding, in general, increases with current. The higher currents and welding speeds which may be used in the submerged melt process tend to improve the efficiency of this type of welding when compared with welding with coated electrodes.

4. The consumption of Unionmelt for a given current, in general, increases linearly with the operating voltage.

5. The melting rate of the electrode for both the coated electrode and submerged melt welding, in general, increases with current.

6. The sum of the anode and cathode potentials in the submerged melt process, as measured by the extrapolation of the Unionmelt consumption data, increases as current increases.

7. The area of the weld nugget is, in general, determined by the current and speed of travel for either coated electrodes or submerged melt welding. A change in the type of coated electrodes or grade of Unionmelt used will show some change in the relationship, although the relationship of area to the current raised to the 1.716 power divided by the travel speed is, in general, linear when plotted on logarithmic paper.

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The Welding of High Nickel Alloys to Other Metals

Discussion by N. C. Jessen

The authors are to be complimented on the care and thoroughness with which this investigation was conducted and no less on the clear manner of presentation of the data.

The problem of welding dissimilar metals such as Monel, Inconel, and nickel to steel is becoming more and more important in the fabrication of vessels and systems for corrosive service, high-temperature applications and combinations of the two. It is for this reason that the data presented by Messrs. Pease and Bott is so very timely.

In the plant of the Babcock & Wilcox Co., at Barberton, Ohio, the welding of nickel and Inconel clad plate in thicknesses up to perhaps 4 in. has been a production problem for many years. In one instance a 4-in. thick steel plate clad with $^1/_2$ in. of pure nickel was manufactured into a pressure vessel. The welding groove was so designed that the steel portion could be welded from one side and the cladding was cut back $^1/_4$ in. from each side of the root of the steel weld. A full section bend specimen with the cladding in tension was one of the requirements of the weld tests. The closure welds joining the two sides of the cladding with the root of the steel weld were first made with nickel electrodes of commercial manufacture. During the bend test only some 5% elongation in 1 in. occurred in the nickel deposit before rupture occurred in the nickel weld. Subsequent investigation indicated that failure was caused by an intergranular chain of graphite particles. The carbon content of the weld metal was less than 0.30% and considering that the electrode was of the graphite-coated type, this value is normal. The solubility of carbon in metallic nickel decreases with temperature from over 2% in the molten state to 0.65% at the eutectic temperature to about 0.03% at 932° F. Since we are dealing with welding of nickel on a heavy section of plate, cooling of the weld metal would be quite rapid and carbon in solution at high temperature may have been held in supersaturated solid solution and during the process of cooling rejected to the grain boundaries. This particular joint and many others subsequently were successfully welded with a 25% Cr – 20% Ni electrode sufficiently low in silicon and high in carbon to produce satisfactory welds. Excessive dilution with nickel from the cladding was not a problem since the root of the weld between the two nickel sheets was of the order of $^5/_8$–$^3/_4$ in. wide.

Another problem in joining of dissimilar metals with high nickel-alloy electrodes is the welding of gray cast iron. In light sections such as $^1/_4$–$^3/_8$ in. no particular difficulties are encountered. However, a structural weld between two $1^1/_2$-in. thick cast-iron members presents a different problem. In welding of this type

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The paper by G. R. Pease and H. B. Bott was published in the January 1950 issue of THE WELDING JOURNAL.

it has been our practice to carefully clad or butter the cast-iron faces to be joined, keeping the heat input into the work sufficiently low that the temperature of the work does not exceed, say, 150° F. This butter weld is usually good with little or no evidence of cracking. However, when the balance of the nickel weld metal is deposited severe cracking is encountered. Microstudies of such welds indicate the presence of a considerable amount of graphite both randomly distributed and in intergranular chains. A study of nickel and Monel electrodes with graphite coatings indicated that carbon contents of the deposit vary from about 0.30 to 1.60%. Perhaps the present authors can contribute something on the factors controlling the manner of carbon or graphite distribution in high-nickel weld metals, bearing in mind that one seldom encounters this difficulty except in heavy multipass welds. The 50% nickel – 50% iron electrode coated with a graphitic coating shows the same characteristics. Welding heavy steel sections instead of cast iron also shows similar results. The No. 140 Monel electrode depositing a low-carbon Monel weld metal offers interesting possibilities for a comparative study.

It was particularly interesting to note the authors' comments on the welding of Nickel Alloys with 19–9 Cb electrodes. From our own experience even slight nickel pickups lead to fissuring, particularly since the carbon content of 19–9 Cb is usually 0.10% C. Good weld-metal quality in the case of 19–9 Cb would necessitate a free ferrite content of some 5–10%, otherwise fissured and possibly cracked weld metal results. It would be of interest to hear whether the authors checked the analysis of the 19–9 Cb weld metal and particularly the analysis of the highly diluted top bead.

Perhaps the authors had a definite reason for choosing 19–9 Cb and 18–8 for their stainless weld metals in nickel and Inconel to steel welds rather than 25–20. In our experience 25–20 would appear the better choice by a considerable margin. Monel-to-steel joints will, of course, require the use of Monel or nickel electrodes.

With reference to the welding groove employed by the authors in this work (75° included angle, $^{3}/_{32}$-in. root space, $^{3}/_{32}$-in. land) and the use of $^{5}/_{32}$-in. diameter electrodes throughout, it would appear that dilution was comparatively high in all of the passes and particularly in the first pass. Data regarding the analysis of the weld metals may be of interest.

In closing I wish to again emphasize the importance of this type of investigation to the fabricating industry and express the hope that the present authors will extend their work to the chemistry and metallography of heavy section welds in the high-nickel alloys.

Authors' Closure

The authors are pleased to acknowledge the contributions of Messrs. Jessen and Campbell to this discussion.

Mr. Jessen recalls some disturbing experiences with an iron-diluted nickel weld composition, which he quite properly ascribed to graphite precipitation arising from the limited solid solubility of carbon in nickel. The presence of the iron, of course, had little or no bearing on the matter. Since then, nickel weld compositions have been derived which are structurally much more stable. These improvements have been incorporated into electrodes of more recent production and the increased stability is reflected in our present data.

As Mr. Jessen points out, the welding of cast iron with nickel-cored (or Monel-cored) electrodes involves two dissimilar metal compositions, one of which is a high nickel alloy. However, the problems involved are so unique and, we believe, so generally unrelated to the present discussion that we shall limit ourselves to one or two brief comments. Like Mr. Jessen, we have noted a greater incidence of distress in heavy-section cast iron welds than in light-section welds but we prefer to ascribe this behavior to differences in stress level, rather than to differences in microstructure. We would like to add also that our experiences with nickel-iron cored electrodes do not parallel Mr. Jessen's, but rather indicate a marked improvement in resistance to weld cracking.

In directing the choice of electrodes for joining nickel or Inconel to stainless (or mild) steel toward one of the high nickel-alloy rods, we wished only to bring attention to the potential hazard of a nickel-diluted stainless steel weld composition. We would like to repeat that the practical importance of the resultant fissuring tendencies is not apparent from the data. We recognize, furthermore, as do both Mr. Jessen and Mr. Campbell, that the hazard can be minimized by using a stainless electrode in which satisfactory control of carbon, silicon and phosphorus is assured. Without this assurance, however, the high nickel alloy electrode would seem to be the safer choice. Mr. Jessen's suggested choice of a fully austenitic 25–20 rod seems to us, as it does to Mr. Campbell, to be an even poorer choice than the 18–8 or the 19–9 Cb types for nickel-diluted welds, unless of course, there is some reason, of which we are not aware, to expect better control over electrode composition in this type of electrode than in the others. A contributing factor to Mr. Jessen's successful experience with the 25–20 electrode, we expect, is the low order of dilution by nickel which he experienced.

We have data concerning the chemical analysis of a number of weld compositions, sampled mostly from the top reinforcing passes but also, in one instance, from the center of the welds. This data suggests that dilution by plate was of the order of 20% in the reinforcing passes and higher, perhaps as high as 30%, in the first and second passes.

Mr. Campbell has raised the question of weld soundness. It is true that, in production welding, fabricators have encountered porosity from time to time and in these test welds there was some radiographically detectable unsoundness, particularly when arc blow became troublesome. As surmised, however, there was no gross, property-destroying unsoundness with any of the high nickel alloy electrodes used in this investigation.

Notch Sensitivity of Welded Steel Plate

Criteria for determining transition temperature, rating notch toughness of structural grades of steel when welded and effect of constraint during welding on notch toughness

by L. J. McGeady and R. D. Stout

INTRODUCTION

IN A series of papers[1,2,3] during the past several years, investigations have been reported covering the factors which influence the notch sensitivity of welded steel plate. The testing method has been the longitudinal bead notch-bend test in which the specimen shown in Fig. 1 has been used. It has been possible with this specimen to show the effects of steel composition, heat treatment, welding conditions and mechanical treatment on notch sensitivity, as well as to show the manner in which welding brings about its peculiar effects.

Three phases have been investigated during the past year of the program. They were as follows:

1. Further inquiry into the criteria for determining transition temperature.
2. A rating of the notch toughness of structural grades of steel when welded.
3. Effect of constraint during welding on notch toughness.

For Item 1, it was agreed to send a questionnaire to individuals interested in notch toughness of steel, to learn which of the many criteria available for determining the transition temperature enjoyed general preference.

For Item 2, a number of grades of commonly used structural steel were obtained in two thicknesses and were rated by means of the longitudinal bead bend test both as-rolled and as-welded.

As Item 3, a pilot program was conducted on two series of Lehigh restraint specimens, one with high constraint and the second with low constraint during welding. The specimens were notched and bent at various temperatures to develop transitional behavior.

The results of the investigations are reported in the sections following.

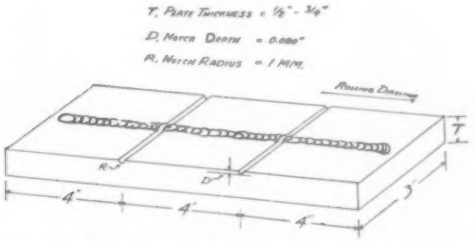

Fig. 1 Longitudinal bend specimen

RESULTS OF THE QUESTIONNAIRE

Questionnaire forms were sent to individuals interested in notch sensitivity, either from the research standpoint or from the production standpoint, with the request that they rate in order of their preference the various criteria of brittleness: ductility, energy absorption, fracture appearance and nominal strength. From the 33 individuals polled, 21 replies were received. The results of this poll, given in the following table, show that ductility measurements or energy measurements were preferred two to one over either fracture appearance or strength measurements. Nevertheless, because no final decision was possible, in all tests reported here, data were recorded to include all four criteria.

Questionnaire Replies Showing Preference for Criterion of Notch Toughness

Ductility	7
Energy	5
Fracture	3
Strength	3
Undecided	3

Examination of these data reveal that for any given steel, one would arrive at the same conclusions in judging embrittlement whether he used ductility data or energy data. For this reason, in the analysis of test results, use was made principally of ductility data obtained by measuring lateral contraction at the root of the notch, which is directly related to bend angle, deflection and other ductility measurements. A lateral contraction of 2% was selected as the transition cri-

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Final report on the Welding Research Council Weldability Project at Lehigh University.

Table 1—Analysis of Steel Plates Used in Welding Research Council Weldability Program at Lehigh University 1948–49

Item No.	Lehigh Univ. identification and thickness, in.	Specifications	C	Mn	P	S	Si	Ni	Cr	Nitrogen wet method
1	BABS-5/8	Am. Bur. Ship.	0.18	0.93	0.014	0.018	0.26	0.09	0.04	0.005
2	B-285-5/8	A.S.T.M. A-285	0.10	0.46	0.012	0.031	0.04	0.05	0.01	0.006
3	A-283-5/8	A.S.T.M. A-283	0.20	0.34	0.013	0.042	0.01	0.11	0.01	0.004
4	A-212-5/8	A.S.T.M. A-212	0.25	0.83	0.014	0.034	0.24	0.06	0.02	0.004
5	B-201-5/8	A.S.T.M. A-201	0.17	0.55	0.020	0.024	0.27	0.07	0.01	0.006
6	B-283-5/8	A.S.T.M. A-283	0.17	0.78	0.018	0.019	0.04	0.02	0.02	0.004
7	B-212-5/8	A.S.T.M. A-212	0.24	0.58	0.014	0.021	0.20	0.09	0.01	0.005
8	A-285-5/8	A.S.T.M. A-285	0.10	0.30	0.011	0.024	0.01	0.09	0.05	0.004
9	B-48s-5/8	U. S. Navy 48s-5	0.16	1.08	0.025	0.022	0.26	0.08	0.06	0.004
10	A-285-1	A.S.T.M. A-285	0.13	0.32	0.011	0.028	0.01	0.06	0.01	0.006
11	B-48s-1	U. S. Navy 48s-5	0.17	1.10	0.024	0.032	0.26	0.15	0.07	0.003
12	A-212-1	A.S.T.M. A-212	0.29	0.85	0.013	0.031	0.25	0.12	0.01	0.004
13	BABS-1	Am. Bur. Ship	0.25	0.82	0.016	0.024	0.05	0.10	0.02	0.006
14	B-285-1	A.S.T.M. A-285	0.08	0.47	0.017	0.032	0.04	0.04	0.01	0.002
15	B-212-1	A.S.T.M. A-212	0.32	0.73	0.013	0.022	0.21	0.01	0.01	0.004
16	B-201-1	A.S.T.M. A-201	0.17	0.50	0.021	0.033	0.21	0.04	0.02	0.002
17	B-283-1	A.S.T.M. A-283	0.25	0.50	0.019	0.028	0.05	0.03	0.01	0.003
18	A-283-1	A.S.T.M. A-283	0.25	0.37	0.013	0.039	0.01	0.07	0.01	0.005

terion. The fracture transition temperatures were selected at the level of 50% shear in the fracture.

SURVEY OF STRUCTURAL GRADES

Six grades of structural steel were ordered in two thicknesses of plate, 5/8 and 1 in. In only three cases, the 1-in. plate came from the same heat as the 5/8-in. plate.

The steels represent a wide range of chemical analysis as well as a variety of mill practices, having been secured from two manufacturers, one of whom supplied six of the grades of steel while the other supplied three additional steels within the same six grades. Chemical analyses of the steels and deoxidation practices are given in Tables 1 and 2.

The steels were tested in several conditions: as-rolled, as-welded at 10 in. per minute with 3/16-in. E6010 electrode at 175 amp., and as-welded at 8 in. per minute with 1/4-in. E6010 electrode at 275 amp. Four of the steels were selected for testing in the welded condition after prenormalizing. The same four steels were tested by the V-notch Charpy impact test. In addition three steels in 5/8-in. thickness only were selected to determine the effect of post-heating at 1150° F. after welding. These data are given in Tables 3 and 4.

TEST RESULTS

Figures 2 and 3 show in graph form the performance data for the nine steels as-rolled and also as-welded at 10 in. per minute at 175 amp. The steels are ordered from left to right according to welded behavior, proceeding from low-transition temperatures or good performance at the left toward higher transition temperatures or poorer performance at the right. The loss of toughness due to welding is seen as the difference in temperature between the height of the open bar and the height of the cross-hatched area. In one case (Fig. 2) damage by welding was not apparent as measured by the 2% lateral contraction criterion. (This steel, A212, was most unusual in several respects and more will be said of it later.)

Table 2—Deoxidation Practice and Finishing Temperatures

Steel	Thickness, in.	Tons of metallic charge	Furnace additions (lb.) FeMn	Spiegel	SiMn	Other	Ladle additions (lb.) FeMn	FeSi	Al	FeTi	Coal	Other	F in temp., ° F.
A212	5/8	144	3150	...	...	...	...	1680	240	350	320	...	1675
Mfgr. A	1	...	...	...	...	...	...	...	...	...	...	...	1580
A283	5/8	110	...	...	...	...	700	...	12	...	160	...	1600
Mfgr. A	1	108	...	...	...	...	800	...	25	...	480	...	1650
A285	5/8	108	...	...	...	...	700	...	15	...	...	...	1550
Mfgr. A	1	113	1155	2100	...	...	...	1365	90	...	...	...	
A212	5/8	221	2500	...	1000	...	200	2000	...	800	...	...	
Mfgr. B	1	216	2500	...	1000	...	900	...	...	2800	...	...	
A283	5/8	191	2500	...	...	...	1400	...	...	...	...	500	
Mfgr. B	1	186	2500	...	...	...	...	560	...	...	...	AlSiFer	
A285	5/8	189	...	...	...	...	700	...	...	...	...	1650	
Mfgr. B	1	...	...	...	...	...	...	...	...	...	...	SiMn	
A201	5/8	189	...	...	2500	...	300	...	...	2600	...	...	
Mfgr. B	1	220	...	...	2900	...	700	2000	...	1000	...	...	
ABS	5/8	191	2500	...	...	...	1400	...	...	...	...	AlSiFer	
Mfgr. B	1	...	...	...	...	...	...	...	...	...	...	500	
USN 48s	5/8	221	2750 (low C)	...	2900	135 Ni	1500 SiMn	1700	...	800	...	300 FeV	
Mgfr. B	1	219	2750 (low C)	...	2900	...	1500 SiMn	1700	...	800	...	300 FeV	

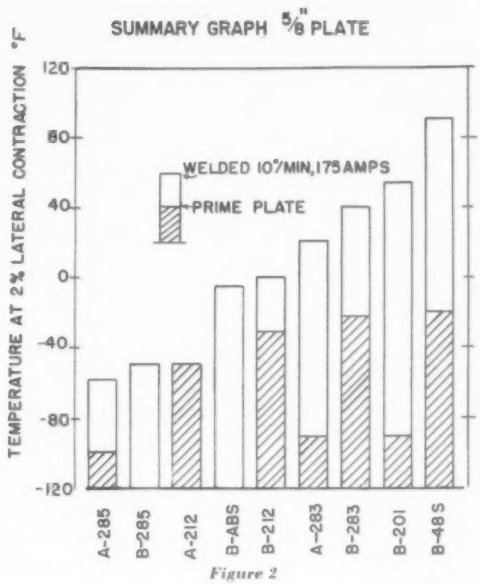

Figure 2

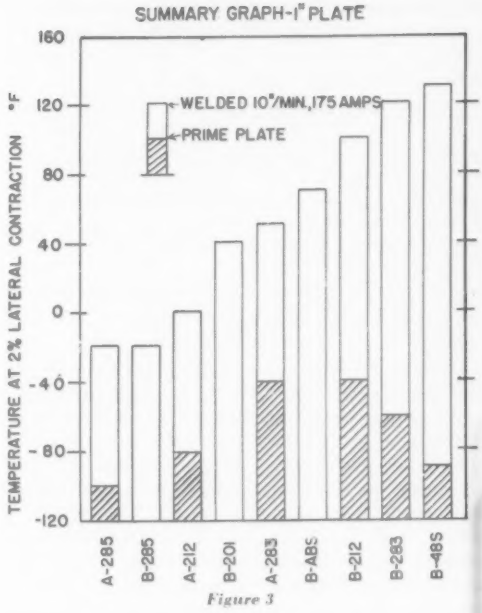

Figure 3

By comparing Fig. 2 with Fig. 3 it is shown that the various grades of steel fall into much the same order of rating for both thicknesses of plate, despite the fact that the 5/8-in. plates were rolled from different heats from the 1-in. plates in 6 of the 9 grades. These figures also show that prime plate behavior gives no indication of the behavior of the welded plate. Steels with identical prime plate transition temperatures have widely different transition temperatures when welded.

It is interesting to note that in the welded condition, the 1-in. plates generally have a transition temperature about 40° higher than the 5/8-in. plate.

While the data for the specimens welded at 8 in. per minute are not shown in graph form, a glance at Table 3 shows that it is a much less detrimental welding condition for most steels than is the low-heat input welding. In those few cases where the transition temperature is higher at the high-welding heat input than at the low rate of heat input, the condition is prob-

Table 3—Summary of Transition Temperatures of Project Steels*

Steel	Thickness, in.	Transition temperature, °F. — 2% Lateral contraction† — Prime plate	Welded, (in./min.) 8	10	Fracture criterion — Prime plate	Welded, (in./min.) 8	10	Vickers hardness welded at 10 in./min. — HAZ‡	Weld metal	Prime plate	T. T., °F., prime plate, 40 ft. lb. Charpy	Transition temperatures Normalized & welded at 10 in./min. — 2% Temp.†	Fract. trans. temp.
B201	5/8	− 90	−15	55	30	30	50	212	181	140			
B201	1	−120	50	40	150	150	140	215					
B212	5/8	− 30	−25	0	10	−25	0	224	190	142			
B212	1	10	140	100	106	160	160	397					
B283	5/8	− 20	−40	40	40	80	60	237	193	131	50	−30	60
B283	1	− 60	80	120	165	160	175	258	193	135	120	90	90
B285	5/8	−120	−85	−50	70	85	75	162	168	115	50	−40	20
B285	1	−120	10	−20			150	160	185	107	100	−10	30
BABS	5/8	−110	−75	− 5	65	80	75	212	187	128			
BABS	1	−120	10	70	160	160	145	262	190	133			
B48s	5/8	− 20	70	90	80	80	90	274	203	166	60	−30	−30
B48s	1	− 90	95	130	100	120	130	302	200	166	100	20	20
A212	5/8	− 50	−50	−50	−30	−45	−40	274	193	164			
A212	1	− 80	20	0	10	20	10	317	215	169			
A283	5/8	− 90	10	20	90	110	90	172	185	140	100	−20	65
A283	1	− 40	60	50		200	200	274			200	50	120
A285	5/8	−100	−80	−60		65	65	157	185	121			
A285	1	−100	−70	−20		155	160	148	203	116			

* All temperatures are in Fahrenheit.
† Temperature at which lateral contraction at root of notch had fallen to 2%.
‡ Heat-affected zone, just below fusion line.

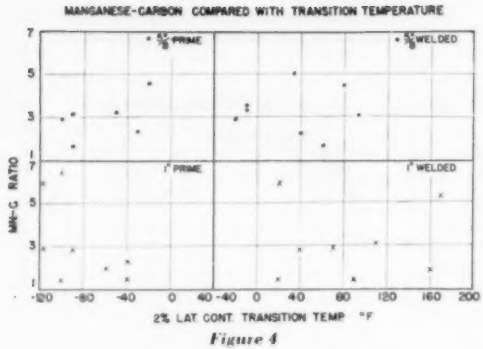

Figure 4

ably due to mechanical effects of the larger heated zone in the absence of any metallurgical differences between heat inputs.

Table 3 also shows that a wide variation exists among the steels as to the temperature at which fracture transition occurs. Again the A212 heats display a remarkably low fracture-transition temperature for medium carbon steels. It will be noted here that welding causes little change in transition temperature of the steels when the appearance of the fracture is used as the transition criterion.

ANALYSIS OF DATA

Among the many suggestions for improvement of steels for welding, one of the foremost has been to keep a high manganese to carbon ratio. With this in mind an effort was made to correlate the behavior of the nine steels with the manganese-carbon ratio. The results are shown in Fig. 4. Neither as-rolled plates nor welded plates display any improvement as the ratio of manganese to carbon increases. In the 5/8-in. plate, four steels which have almost identical carbon contents (about 0.17%) and a range of manganese (from 55 to 1.08%), do not show that notch toughness is improved as a direct function of increased manganese content in either the welded or unwelded condition.

If one seeks to explain the results on welded or prime plate on the basis of carbon content alone, Fig. 5 shows that there is some correlation. Steels of high-carbon content tend to have high-transition temperatures. This effect is shown in a related way by plotting transition temperature as a function of maximum underbead

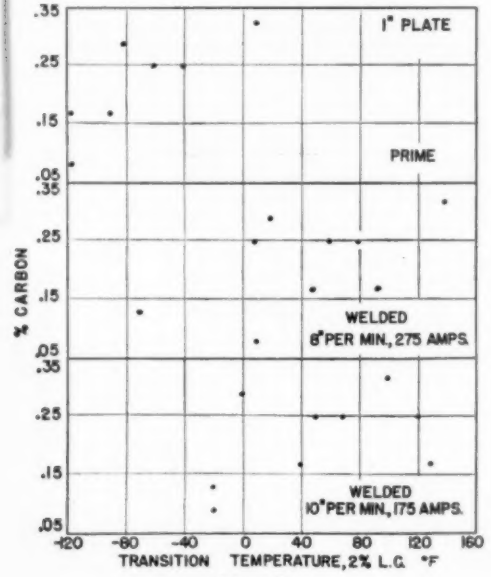

Figure 5

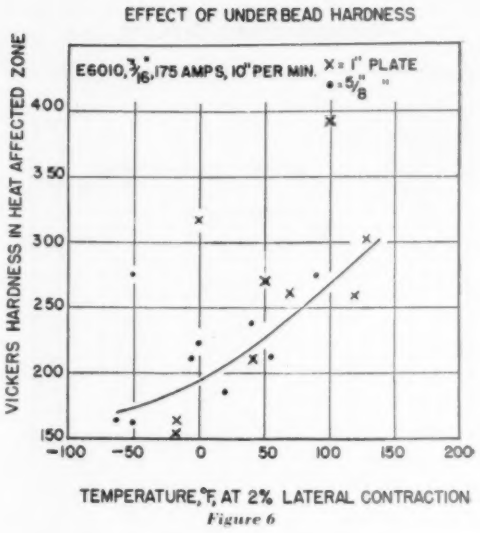
EFFECT OF UNDERBEAD HARDNESS
E6010, 3/16", 175 AMPS, 10" PER MIN. X = 1" PLATE
• = 5/8" "
VICKERS HARDNESS IN HEAT AFFECTED ZONE
TEMPERATURE, °F, AT 2% LATERAL CONTRACTION

Figure 6

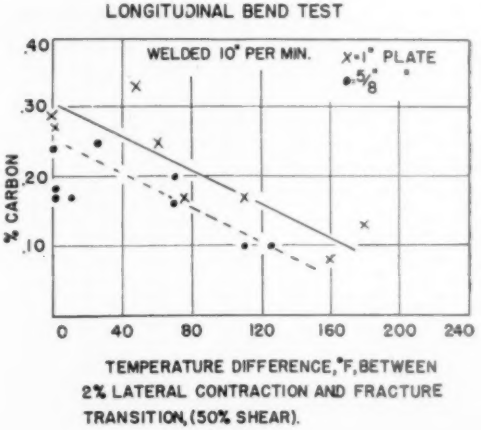

Figure 7

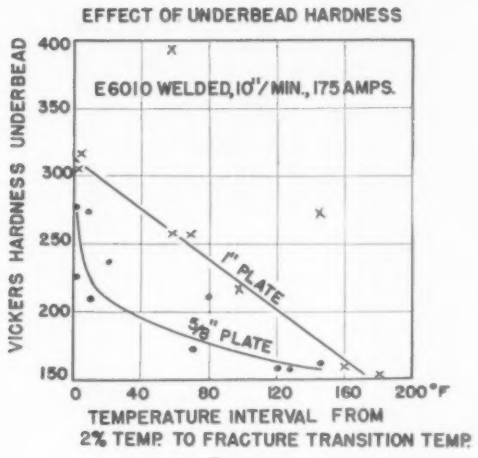

Figure 8

hardness as is shown in Fig. 6. It should be pointed out that here the three points which lie well to one side of the curve are heats of A212.

Carbon has another interesting effect on these nine steels. If one observes for the welded plates, the separation between the 2% transition temperature and the fracture transition temperature, it becomes apparent that as higher carbon-content plates are tested, these two transition temperatures tend to coincide. This effect is shown graphically in Fig. 7. While underbead hardness is not a function of carbon content alone, the same trend exists in Fig. 8 where the separation of the two transition temperatures is plotted as a function of underbead hardness. It should be noted here that welding produced no underbead cracks in these steels.

Although the phosphorus contents of these steels are low, there exists a variation in phosphorus content among them. It was noticed that in welded steels having the same carbon content, those with higher phosphorus content tend to have higher transition temperatures. Therefore since carbon by itself affects transition temperatures, it occurred to the authors that an integrated carbon-phosphorus content might better relate the transition behavior of these steels. After some trials the factor chosen was: % carbon plus 20 times the % phosphorus. These data are plotted in Figs. 9 and 10 and show a surprising correlation. To substantiate

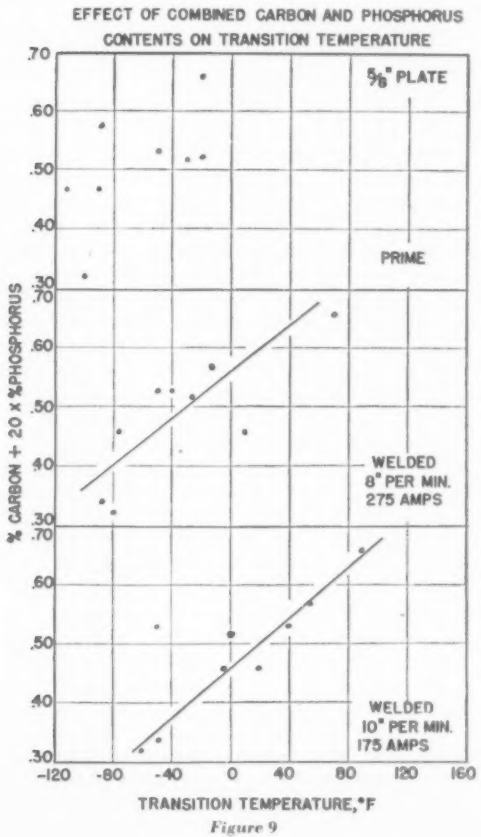

Figure 9

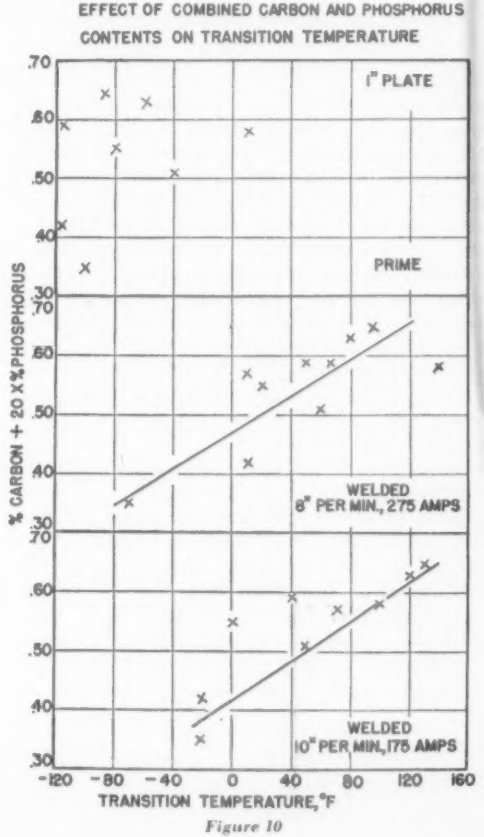

Figure 10

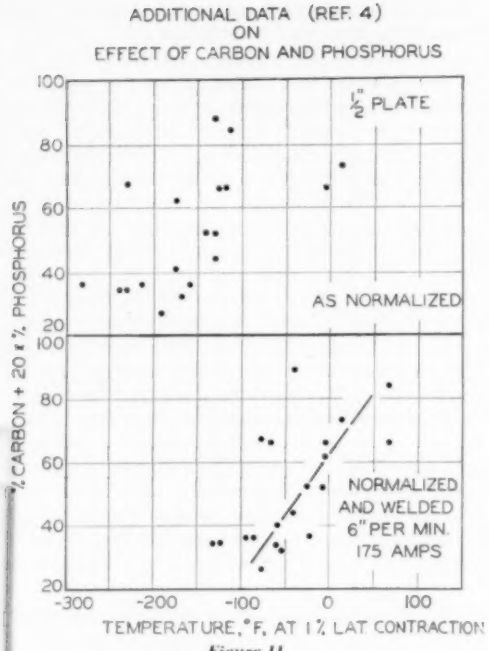

Figure 11

these data, data from other workers were examined and plotted in Fig. 11, showing a somewhat better relation when an integrated carbon-phosphorus variable is used for purposes of plotting instead of carbon alone. It is realized that phosphorus *per se* may not be the influencing factor here but that some associated variable such as mill practice may be responsible. Nevertheless the relationships shown in Figs. 9–11 are difficult to overlook. Before passing, it should be noted that again the points showing unexpectedly low-transition temperatures and lying far off the curve in Figs. 9 and 10 represent the A212 heats, with the exception of one point which represents 1-in. plate of steel A-201.

In Table 3 are listed the performances of those steels which were normalized before welding. All were considerably improved in that either the ductility transition temperature or the fracture transition or both were lowered by the prenormalizing treatment.

Those steels which were welded and then postheated at 1150° F. showed remarkable improvement in ductility over the welded condition. In all three cases performance came up to the properties of the unwelded plate. These data are given in Table 4.

Table 4—Effect of Postheat at 1150° F.

All specimens welded at 10 in. per minute, 3/16 in. E6010, 175 amp., 5/8-in. plate.

Steel code No.	*Transition temperatures, ° F.* As-received 2%	As-received *Fracture*	Postheated 2%	Postheated *Fracture*
B201	55	50	−100	55
A212	−50	−40	− 90	−30
A283	20	90	−100	145

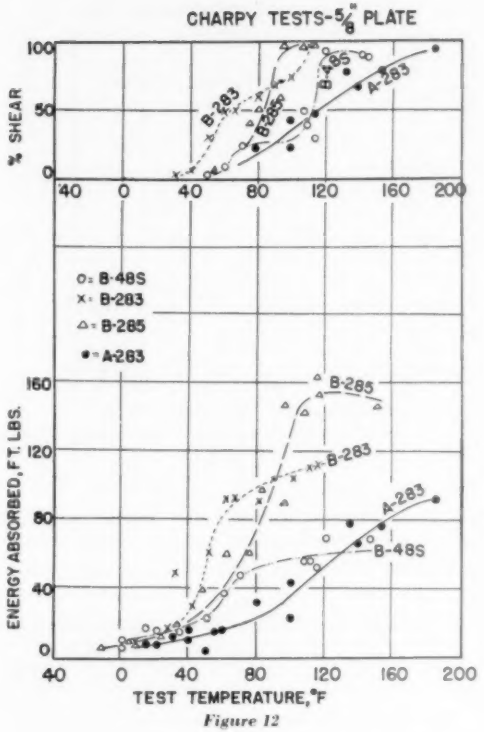

Figure 12

V-notch Charpy impact tests were conducted on the same steels which were selected for the prenormalizing treatment. When 40 ft.-lb. energy absorption was used as the transition-temperature criterion in these tests and compared to the longitudinal bend-test data no correlation existed. However, excellent correlation between the two tests is obtained by comparing the fracture transition temperatures of steels obtained in both tests. The correlation is shown in Fig. 14.

Some investigators have regarded it as significant that in certain test specimens, as testing conditions become more severe, i.e., at lower test temperatures, the maximum load sustained by the specimen before breaking decreases. It has been found that this behavior is shown, although faintly, by the longitudinal bend test. It was decided to conduct a series of tests with welded longitudinal bend specimens in which the test temperature was to be kept constant and the notch severity varied. The steels chosen for studying normalizing were also used for these tests as-rolled and welded. The effect of notch severity on maximum load is shown in Fig. 15. One-hundred per cent load-carrying capacity was determined by bending unnotched longitudinal bend specimens reduced 0.080 in. in thickness to correct for the reduction in cross-section area normally encountered in notched plates. If the severity of notch at which load carrying capacity drops is used as the embrittlement criterion, the steels fall into much the same order as given in Fig. 3. In Table 5 the yield-

Table 5—Variable Notch Study Data

1-in. plate, 5/16 in. E6010, 10 in. per minute, 175 amp., All tests at 0° F.

Steel		*0.01 in. R*	*0.04 in. R*	*0.067 in. R*	*0.125 in. R*	*0.19 in. R*
B283	Yield point*	21,000	21,000	21,800	20,000	20,800
		21,000	21,000	21,400	20,000	20,200
	Ultimate strength*	24,000	23,000	32,400	36,200	36,500
		24,000	27,300	31,700	35,800	36,300
	Lateral contraction, %	0.53	0.49	1.8	4.0	3.9
		0.47	0.93	1.4	3.5	4.3
B285	Yield point	19,200	19,000	18,600	18,200	18,500
		19,200	18,600	18,900	18,300	
	Ultimate strength	27,200	31,800	37,300	32,100	32,800
		29,000	29,900	33,000	32,400	
	Lateral contraction, %	2.2	4.8	..	8.9	..
		2.7	3.8	..	9.4	10.2
B48s	Yield point	30,000	26,000	27,500	29,000	30,000
		30,100	26,000	27,800	28,000	29,000
	Ultimate strength	33,000	32,000	30,500	40,000	46,000
		31,000	34,000	30,700	41,000	46,400
	Lateral contraction, %	0.43	0.9	1.2	2.1	3.1
		0.69	0.9	1.2	1.7	3.3
A283	Yield point	23,000	23,000	22,400	22,500	21,500
		22,400	22,000	22,000	22,000	20,300
	Ultimate strength	2,300	30,000	32,200	34,800	39,300
		22,700	31,400	32,400	34,000	36,700
	Large contraction, %	0.6	1.3	1.9	2.3	4.7
		0.6	1.2	1.8	2.2	3.8

* Measured in terms of the load in pounds on the bend specimen.
All specimens in this series failed by cleavage fracture.

point load, maximum load and lateral contraction are listed for these tests. It is generally known that as testing temperature decreases, yield point increases. However in the tests in which notch severity was varied, Table 5 shows that the yield point remained constant while the nominal ultimate strength decreased. This fact points out a difference in the mechanics whereby notch acuity and testing temperature produce loss in toughness in steel. Observations of lateral contraction on this series of tests showed that the steels would be rated in much the same order as in Fig. 3.

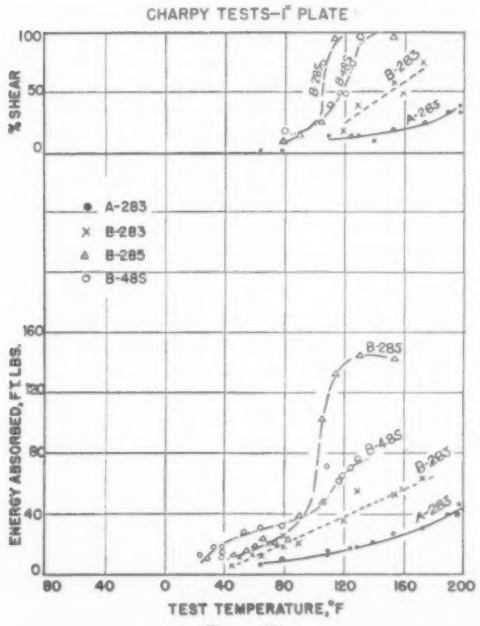

Figure 13

CONSTRAINT DURING WELDING AND NOTCH SENSITIVITY

In the production of a welded joint there is always a constraint imposed by reaction between the cooling and contracting weld zone and the rest of the steel structure, which resists the movement of the contracting metal. As a result residual tensile stresses approaching the yield point will be present in the weld zone when it reaches ambient temperatures. These residual stresses have been viewed with suspicion as to their possible harmful effects on the service proper-

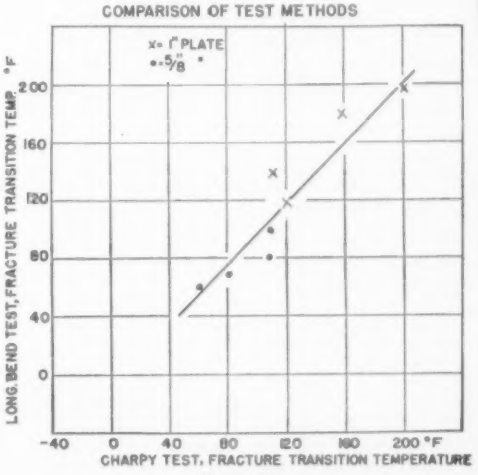
COMPARISON OF TEST METHODS
x= 1" PLATE
•=5/8" "
LONG. BEND TEST, FRACTURE TRANSITION TEMP. °F
CHARPY TEST, FRACTURE TRANSITION TEMPERATURE

Figure 14

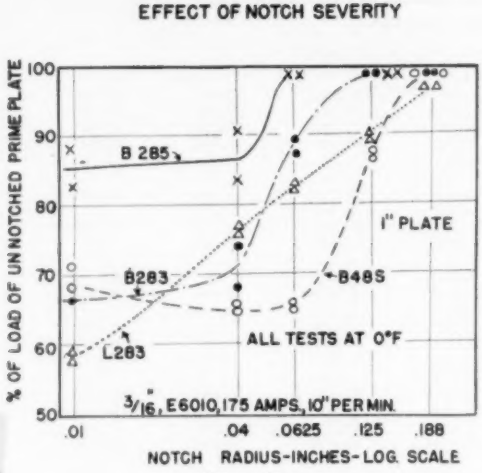

Figure 15

ties of the weldment. Previous investigations[5,6] have in general failed to demonstrate that they are detrimental, but there is still considerable doubt as to their effect.

The Lehigh restraint specimen[7] offers a convenient method of introducing quantitatively variable constraint on a butt joint during welding. It was decided to run a few tests in which one series would be welded with high constraint and a second series with minimum constraint. Each series would then be notched and tested in bending over a range of temperatures to develop transitional behavior. Any differences developed between the two series could reasonably be ascribed to the variation in constraint present during welding.

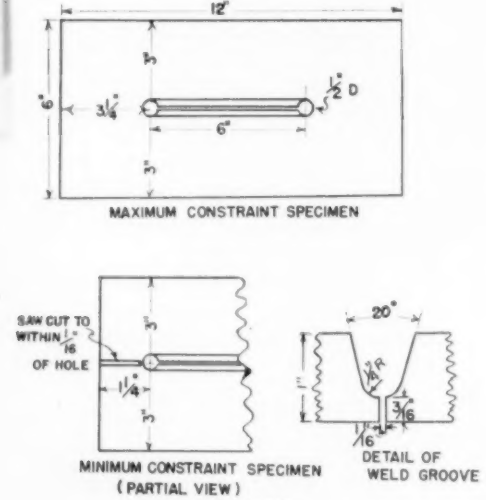

Figure 16

The specimens used to obtain high and low constraint are shown in Fig. 16. A single bead was deposited with 3/16 in. E6010 at 200 amp. and 10 in. per minute. Penetration was such that weld metal extended almost to the bottom side of the specimen. A notch identical to that shown in Fig. 1 was machined at right angles to the weld axis at the plate center on the bottom side. Bend testing was conducted with the notched side in tension. The 1-in. plate used for the specimens analyzed:

	%
C	0.25
Mn	0.66
Si	0.19
P	0.020
S	0.022

In order to learn the magnitude of the residual stresses present in the two types of specimens, SR-4 rosette gages were attached after welding to the bottom side of the plate at the center of the weld and just alongside the weld root. The gage area was then sawed out of the plate and stresses computed by relaxation. In the table below these stresses are summarized. Each value is the average of five determinations.

Residual Stresses in Constraint Specimens

	High constraint	*Low constraint*
Longitudinal stress	+19,000 psi.	+ 6,000
Transverse stress	+31,000 psi.	+15,000

These measurements can be expected to serve only as an indirect indication of the stresses in the immediate weld zone, since the gage was to one side of the weld and failed to take into account the steep stress gradient that exists close to the weld. Nevertheless they are of some use for comparison purposes.

During the bend testing, observations were recorded for energy absorption, lateral contraction 1/32 in. below the notch and fracture appearance. The specimens were immersed in a coolant during testing and were bent with a head speed of about 1/4 in. per minute. The results are plotted in Figs. 17–19. No real difference can be found in the behavior of the two series of

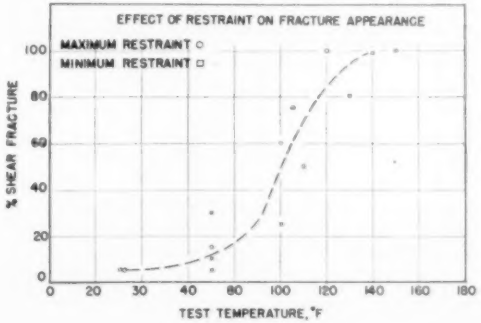

Figure 17

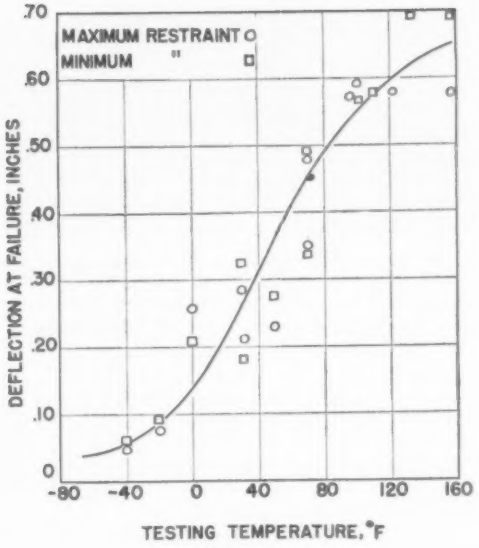

Figure 18

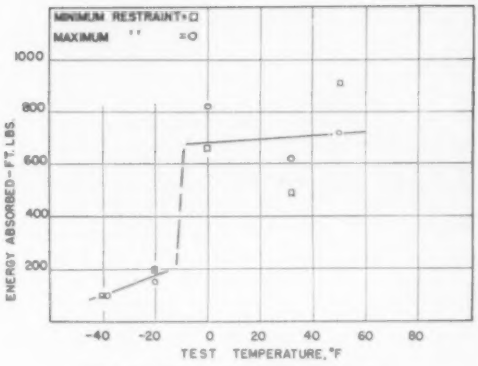

Fig. 19 Effect of specimen restraint

plates by any of the three criteria. These tests, therefore, supply further evidence that, assuming sound welds, constraint during welding, and the residual stresses induced thereby, do not appear to influence the notch toughness of a welded joint.

SUMMARY

The results of the investigation reported here can be summarized as follows:

1. A questionnaire was sent to men interested in the effect of welding on notch toughness to discover which criterion they prefer to use to select transition temperatures. Ductility and energy absorption were preferred two to one over fracture appearance or nominal strength.

2. Fifteen heats of steel representing two thicknesses of plate, six structural grades and a variety of mill practices have been rated in notch toughness by the longitudinal-bead notch-bend test. The grades of steel fall in much the same order in either $^5/_8$ or 1 in. thickness. The behavior of as-rolled plate gives no indication of the characteristics of welded plate.

3. No correlation was found between manganese-carbon ratio and transition temperature in either as-rolled or welded plate.

4. A rough agreement between heated-zone hardness and transition temperature confirmed previously published results.

5. Although all of the steels contained normal phosphorus contents, a surprising correlation was developed between C content plus 20 times phosphorus and transition temperature of welded plate. It is interesting that no such relation was present in as-rolled plates. Data from other investigators confirmed this relation.

6. Transition temperatures from Charpy tests could not be correlated with those of slow notch-bend tests except on the basis of fracture appearance.

7. The Lehigh restraint specimen was used to produce welds under high and low constraint. The specimens were then notched and tested in bending over a range of temperatures. No effect of the constraint during welding on the notch toughness could be shown. Significantly different residual stresses were measured in the high and low constraint specimens.

ACKNOWLEDGMENT

The project reported here has been carried out under the auspices of the Welding Research Council. The authors appreciate the valuable guidance furnished by the Lehigh Subcommittee, including R. E. Somers, Chairman, and Messrs. Aborn, Adams, Boardman, Jennings and Swan, and also the encouragement and advice of W. Spraragen.

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Test of H-Section Welded Truss

A strain-gage test and an analysis of an 80-foot H-section welded truss. Measured stresses and deflections were found to be in close agreement with the theoretical

by A. T. Waidelich

STRAIN-gage tests made on an 80-ft. welded truss provided an unusual opportunity to compare measured stresses and deflections with the corresponding computed values, including the secondary effects of the restraint at the truss joints.

This comparison is of particular interest because the H-Section Truss, which has no gusset plates, is in unusually close agreement with the assumption in the common truss theory that each truss member has a constant section for its full length.

THE H-SECTION TRUSS

In 1943 The Austin Co. developed the H-Section welded truss which is particularly well adapted for use in the roofs of large industrial plants. The development and peculiar advantages of this truss have been previously presented[1] and are not within the scope of this paper. In 1944 an H-Section truss of 50-ft. span was tested to failure.[2] At that time it was not considered practicable to make any measurements other than deflection. However, the development of the SR-4 strain gage provided a simple practical tool for the more detailed analysis of truss action and several years ago a research program was authorized, one part of which included the test of an 80-ft. H-Section Truss. It is this test which is described in this paper.

Figure 1 gives the dimensions and sections used in the 80-ft. trusses which were tested.

The H-Section truss may be defined as a truss in which all members are conventional *H* or *I* rolled structural shapes, with the webs of all members lying the same vertical plane, and with all connections made at abutting surfaces of these sections by fillet welds. The character of this type of truss is shown by Figs. 1, 2 and 3. Each member was placed so that its web laid in a common vertical plane. The ends of the web members were cut to the correct slope and length by an abrasive saw and the truss was assembled in a jig which preserved all dimensional relationships.

Continuous fillet welds were made at all abutting surfaces. These were $^5/_{16}$ in. except at U_0 and U_{12} where $^3/_8$-in. welds were applied. At most connections these welds need not be continuous for adequate strength but are made so to completely seal all cut surfaces. This improves the resistance to corrosion by eliminating all cracks and pockets, and leaves exposed only the original rolled surfaces of every member.

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Presented at the Thirtieth Annual Meeting, A.W.S., Cleveland, Ohio, week of Oct. 17, 1949.

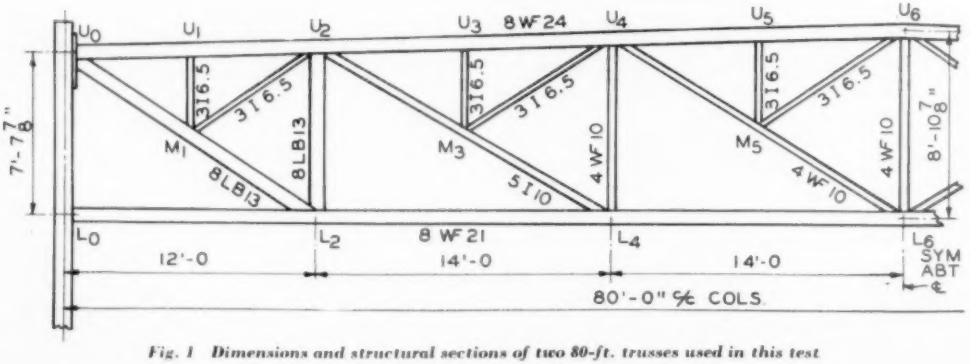


Fig. 1 Dimensions and structural sections of two 80-ft. trusses used in this test

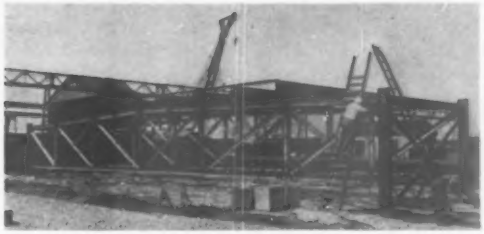


Fig. 2 Completed 80-ft. test structure at start of strain-gage installation

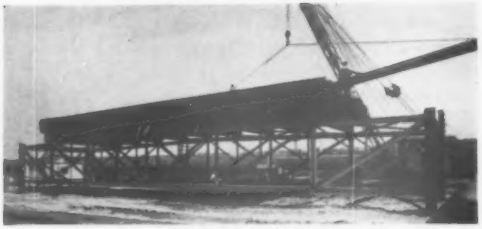


Fig. 3 The test structure being loaded with 60-ft. lengths of stock beams

Purlins were of different heights to allow steel to be piled level

The truss was fabricated with a camber of 1 in. at L_6, $^3/_4$ in. at L_4 and L_8, and $^3/_8$ in. at L_2 and L_{10}.

Two of these 80-ft. trusses were used in the test. They were not specially designed or fabricated for this test but were taken at random from a stock on hand. These trusses were designed for a total uniformly distributed load of 58 lb. per square foot of roof surface (23 lb. dead load plus 35 lb. live load) with the trusses spaced 20 ft. apart.

TEST ASSEMBLY

The test was conducted in the yard of The Austin Co.'s fabricating shop at Euclid, Ohio. The completed test structure is shown in Fig. 2.

The four columns were 10WF49 with their bases 4 ft. below the center line of the bottom chord. For convenience in installing strain gages and handling the load, the footings were depressed so that the bottom chord was only about 2 ft. above the ground.

The footings were 6 ft. square to minimize their settlement.

The two 80-ft. trusses were placed 17 ft. apart. The vertical bracing consisted of angles between the columns and $^3/_4$-in. rods at the second, sixth and tenth panel points. Bottom chord struts were also placed at these three panel points. The top chords had a complete system of angle X-bracing.

The test load consisted of steel beams with a maximum length of 60 ft. and therefore required only nine purlins (see Fig. 3). Since the trusses were double-pitched, purlins of different depths were used. These rested on beveled plates and fills so that the webs of all purlins were vertical, and so that the tops of all purlins would be at the same level when the camber had been taken out of the trusses. A light angle welded to the top of the purlins, on both sides, tied them together and acted as a guard to prevent the bottom layer of steel from sliding off the ends of the purlins.

Each end of each truss was connected to the column by fourteen $^3/_4$-in. drive-bolts. These were used to facilitate dismantling at the completion of the tests.

The bottom chord connections to the columns—theoretically not stressed—were made different on the two trusses to observe whether there was any appreciable difference in their action. For the north truss these connections were a single clip angle welded to the columns and two unfinished bolts in the bottom flange of the bottom chord. For the south truss, these connections were a pair of angles welded to the bottom chord webs and connected to the column by four unfinished bolts.

Except for these bottom chord connections the two trusses were the same.

STRAIN GAGES

For each loading condition, 72 strain-gage measurements were taken on each truss, or a total of 144 for both trusses. Gages were placed at the same points in both trusses to provide a check. The majority of the gages were located around joints U_6 and L_2, but a few were placed at the center of several main members. The specific location of these gages will be given, later, along with the discussion of their readings.

All gages were of the SR-4 type A-5 or AX-5, which had a $^1/_2$-in. gage length.

The readings of these gages were recorded automatically by three sets of scanning recorders and 48-point scanning switches.

Figure 4 shows the instruments which were housed in a construction shed adjacent to the test assembly.

The original thought had been that the three recorders would be operated simultaneously, but it was practicable to bring only one power line to these re-

Fig. 4 Scanning recorders and 48-point scanning switches used to record results of test

These were housed in a construction shed near the test area

corders and it was observed that the operation of one recorder produced slight movements in the needles of the other two recorders. Therefore the recorders were operated in sequence. Even so it was possible to take the 144 readings in less than 2 min.

The strain-gage tests, including all installation, wiring and operation, were made by members of the Warner Laboratory of Case Institute of Technology under the direction of Prof. H. D. Churchill. A number of practical problems had to be solved and the installation of the gages and instruments required about five days.

The application of the gages was carried out in four steps: preparation of the steel surface, applying gages, wiring gage to recorder and testing gage.

The preparation of the steel surface was hampered by the shop coat of specially formulated zinc chromate paint which had been applied when the trusses were fabricated four months previously. This paint was removed from the gage locations by repeated use of a blow torch and by scraping with a steel tool. Finally the bright metal was exposed by use of a hand emery wheel. This operation is shown in Fig. 5.

The gages were then cemented to the steel with No. 5458 Du Pont Adhesive, using a pressure of approximately 2 lb. A small square of sponge rubber was then placed over the gage, and a wood block placed over the rubber and wired in position. One of these blocks over a gage is shown on the near diagonal member in Fig. 5.

Twenty-four hours were allowed for the adhesive to set and then the gages were connected to the scanning switches by No. 18 wire. These wires were securely fastened to the trusses at intervals to prevent any movement which might damage a gage. More than three miles of wire were required to connect the gages to the recording instruments.

To compensate for temperature variations, dummy gages were placed on a length of structural steel below the trusses and connected into the circuit of the scanning recorders.

Fig. 5 Paint removal and steel polishing prior to installation of SR-4 strain gages

As the wiring progressed each gage was tested with a portable ohmmeter to check for shorts and grounds. If the gage passed this test it was then given a heavy coating of petrolatum to prevent moisture from penetrating into the gage. This precaution was essential not only because this test was made out-of-doors, but also because of the time during which the gages had to remain serviceable. Some of the gages were installed as early as April 26th, whereas the tests were not completed until May 6th.

MEASUREMENT OF DEFLECTION

The vertical deflection of the four columns and the main vertical members of both trusses were measured during the tests. Specially prepared scales (two of these scales are shown in Fig. 6) were cemented to the steel and an engineer's level was located so that all 14 scales could be read from one setup.

All readings were made directly, to the nearest sixteenth of an inch.

TEST PROCEDURE

The earlier test on 50-ft. trusses had demonstrated the practicability and ease with which large loadings could be applied to such structures by using lengths of structural steel shapes. The same method was therefore adopted for the 80-ft. truss test. However, at the time of this test, structural steel was in extreme demand and stocks were below normal so that the loading had to be devised out of whatever material was on hand.

The loading pattern consisted of six layers of beams 60 ft. long varying from 30-in. sections on the bottom to 18-in. sections on top. Between the first and second layer and between the fourth and fifth layers, 10-in. beams, 20 ft. long, were placed at right angles to the

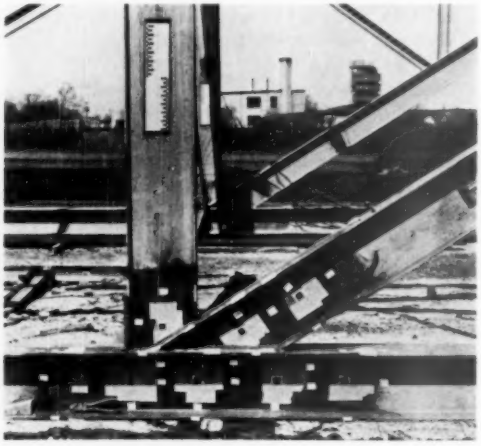


Fig. 6 Specially prepared scales were cemented directly to the vertical members of the truss so vertical elevations could be read during test

Joint shows SR-4 strain gages before completing wiring to recorders

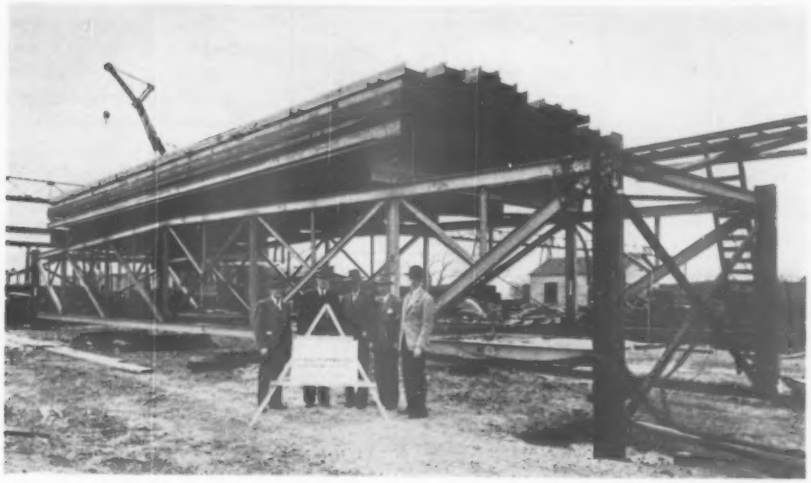


Fig. 7 Maximum test load of 254 kips. applied to test structure

When this peak load was removed these trusses showed a maximum residual deflection of 1/8 in.

other load beams, and directly above the purlins. These smaller beams were required to separate layers of beams with different flange widths which would have prevented nesting the steel. Figure 7 shows the maximum load in place.

All loads were computed from the nominal weights of the sections used. The base load was 24 kips. which included the trusses, purlins and truss-bracing, before applying any load on the purlins.

Two complete tests were made. In Test 1 the load was built up from 24 to 174 kips. and then the applied load was removed. In Test 2, the load was run up to 254 kips. in seven steps; and then removed. The loading steps used in the two tests are listed in Table 1.

Table 1—Test Loads at Which Readings Were Taken

Test 1		Test 2	
Load, kips.	*Date of readings*	*Load, kips.*	*Date of readings*
24	5-1-46	24	5-2-46
89	5-1-46	89	5-2-46
174	5-1-46	174	5-2-46
89	5-1-46	196	5-2-46
24	5-2-46	196	5-3-46
...	...	220	5-3-46
...	...	237	5-3-46
...	...	254	5-3-46
...	...	220	5-3-46
...	...	196	5-3-46
...	...	196	5-6-46
...	...	174	5-6-46
...	...	89	5-6-46
...	...	24	5-6-46

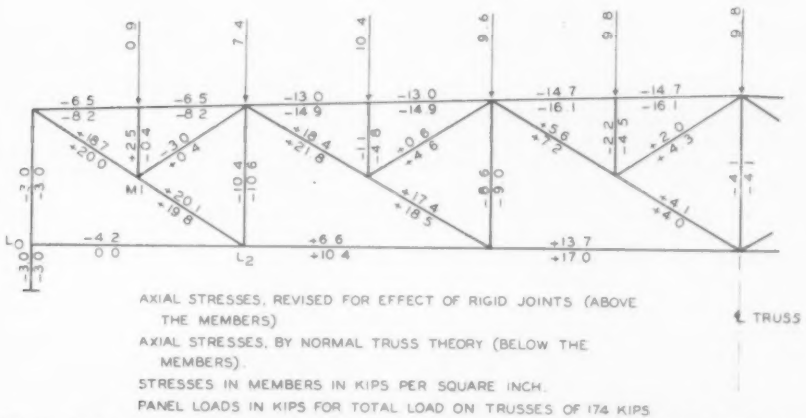
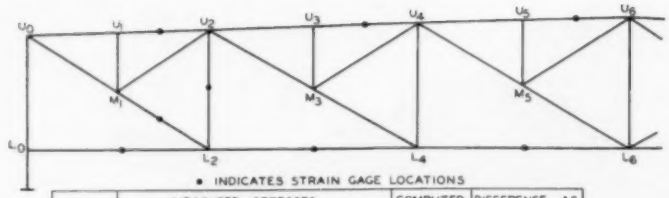

AXIAL STRESSES, REVISED FOR EFFECT OF RIGID JOINTS (ABOVE THE MEMBERS)
AXIAL STRESSES, BY NORMAL TRUSS THEORY (BELOW THE MEMBERS).
STRESSES IN MEMBERS IN KIPS PER SQUARE INCH.
PANEL LOADS IN KIPS FOR TOTAL LOAD ON TRUSSES OF 174 KIPS
℄ TRUSS

Fig. 8 Axial stresses computed by normal truss theory, revised by including effect of rigid joints



• INDICATES STRAIN GAGE LOCATIONS

MEMBER	MEASURED STRESSES			COMPUTED (REVISED)	DIFFERENCE AS % OF COMPUTED
	NORTH TRUSS	SOUTH TRUSS	AVERAGE		
$L_0 L_2$	-1.6	-2.6	-2.1	-4.2	-50
$L_2 L_4$	+7.0	+7.3	+7.2	+6.6	+9
$L_4 L_6$	+13.3	+13.0	+13.2	+13.7	-4
$U_1 U_2$	-8.0	-6.7	-7.4	-6.5	+14
$U_3 U_4$	15.6 *	-12.9	-14.3	-13.0	+10
$U_5 U_6$	-18.7	-15.7	-17.2	-14.7	+17
$M_1 L_2$	+16.2	+18.3	+17.3	+20.1	-14
$U_2 L_2$	-12.5	-10.0	-11.3	-10.4	+9

* ACTUAL READING, BUT APPARENTLY INVOLVES AN EXPERIMENTAL ERROR. THIS POINT WAS NOT PLOTTED ON FIGURE 10 SINCE IT FALLS CONSIDERABLY OFF THE CURVE.

Fig. 9 Comparison of measured and computed stresses for 174 kip. loading for 80-ft. truss test

The 174-kip. load corresponds approximately to the design load of the truss, and the 254-kip. load to the dead load plus twice the live load. This relationship is not precise since the truss design is somewhat unbalanced for the test load which rested on only the nine interior panel points whereas the original design was for a load uniformly distributed over all the panel points.

COMPUTED STRESSES

To secure a fair comparison of the measured and theoretical stresses and deflections, an analysis was made of the secondary stresses caused by the restraint at the joints of the truss. These stresses were computed for one loading only: the 174-kip. load.

The axial stress and the change in length of each member were obtained from the conventional stress diagram. From these a Williot Diagram was drawn which gave the relative displacement of each end of each truss member with respect to the opposite end. The fixed-end moments at the ends of the members were computed and then were balanced by moment distribution.

With the truss members carrying secondary moment, shears exist which destroy the static equilibrium at each joint. Therefore, the original stress diagram was redrawn to include these shears and to yield a revised set of axial stresses.

Using these revised axial stresses the previous train of computations was repeated to yield a further revision in the axial stresses. This second revision produced very small changes and the refinement of further repetitions of this computation was considered unwarranted.

Figure 8 compares the two sets of computed axial stresses: those derived from the normal truss theory ignoring the restraint at the joints; and those obtained including the effects of the rigid joints. These figures show that the effect of the restraint at the joints is generally to reduce the axial stress in the main truss members. An exception is the end diagonal M_1L_2 which has its tension increased as a result of the secondary compression in the member L_0L_2.

COMPARISON OF MEASURED AND COMPUTED STRESSES

For the 174 kip. loading, Fig. 9 compares the revised computed axial stresses with the actual stresses where these were available from strain-gage readings. These strain-gage locations are shown on this figure.

Figure 10 gives a representative comparison of the computed and measured unit axial stresses as they varied with the loading, for two members of the truss: U_3U_4 and L_2L_4. Separate curves are shown for the two computed values: "unrevised" being computed by the normal truss theory, and "revised" including the secondary effect of the restraint of rigid joints. For each member there are two measured stresses: one for each truss.

There is a reasonable agreement between the computed and measured stresses in Figs. 9 and 10. The differences can be caused by at least four factors:

1. Normal experimental errors.
2. The computed unit stresses are based on the handbook areas of the sections and were not checked by direct measurement. Permissible variations of these areas from the theoretical are $2^1/_2\%$ plus or minus.
3. The load on the trusses was also computed from the handbook weights and is subject to the same variation of $2^1/_2\%$ plus or minus.
4. Unequal distribution of the load between the two trusses. Every effort was made to divide the load equally but 127 tons of steel in 60-ft. lengths cannot be piled up with mathematical precision.

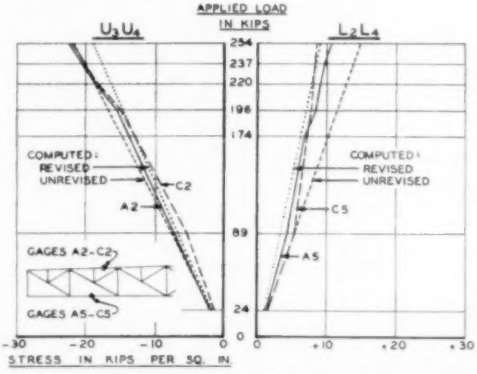
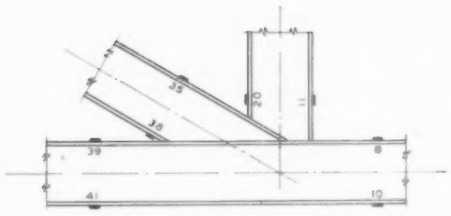


Fig. 10 Comparison of computed and gage stresses in two chord members

Gages A2 and A5 on north truss, C2 and C5 on south truss



JOINT L2

GAGE	NORTH TRUSS STRESS COMP.	NORTH TRUSS STRESS MEAS.	NORTH TRUSS MOMENT COMP.	NORTH TRUSS MOMENT MEAS.	SOUTH TRUSS STRESS COMP.	SOUTH TRUSS STRESS MEAS.	SOUTH TRUSS MOMENT COMP.	SOUTH TRUSS MOMENT MEAS.
41	···	+1.3	···	+72.0	···	+1.7	···	+78.3
39	···	−8.7			···	−7.0		
38	+18.1	+14.8	-19.7	-34.0	+18.1	+15.8	-19.7	-40.0
35	+22.1	+21.5			+22.1	+23.7		
20	-14.8	-19.2	-41.0	-74.1	-14.8	-18.0	-41.0	-69.6
11	−6.3	−4.2			−6.3	−3.9		
8	+10.3	+8.3	+67.5	+18.2	+10.3	+10.9	+67.5	+57.6
10	+2.8	+4.5			+2.8	+4.5		

STRESSES IN K/SQ. IN., MOMENTS IN IN. KIPS.

Fig. 11 Computed and measured moment and stress at joint L_2 for 174-kip. load

The above comments apply equally well to all following comparisons of measured and computed stresses and deflections.

At two joints in each truss, U_0 and L_2, strain gages were placed on the flanges of the intersecting members so that the actual moments in these members might be determined. Typical values for joint L_2 are given in Fig. 11.

All these gages were on the flanges of the various members and close to the joint. As a result they not only reflect the secondary effect of the bending due to the restraint at the joint, but they are affected by their proximity to the junctions of the flanges of different members with consequent local disturbance of the stress pattern. Despite this local effect, there is reasonable agreement between the computed stresses and those determined from the gage readings. However, the differences are magnified in the comparison of moments. The differences in the measured stresses for the north and south trusses may be explained by the four factors previously mentioned in discussing joint L_2. Note Fig. 10. In addition, for gages 41 and 39, the difference in the connections at L_0 undoubtedly had some effect.

COMPARISON OF MEASURED AND COMPUTED DEFLECTIONS

As previously described, the deflection of each panel point of both trusses was measured to the nearest sixteenth of an inch with an engineer's level. In determining the actual deflections of the truss, allowance was made for the settlement of the four end posts which

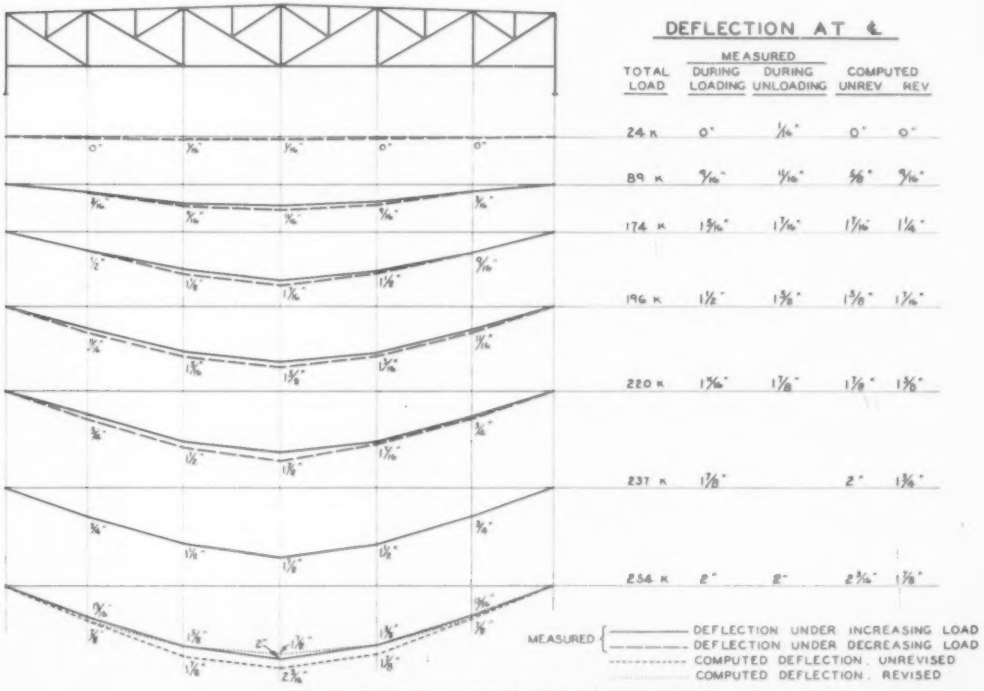

DEFLECTION AT L
MEASURED
TOTAL LOAD
DURING LOADING
DURING UNLOADING
COMPUTED UNREV
COMPUTED REV
24 K 0" 1/16" 0" 0"
89 K 5/16" 1/16" 5/8" 5/16"
174 K 1 3/16" 1 1/16" 1 1/16" 1 1/4"
196 K 1 1/2" 1 5/8" 1 5/8" 1 7/16"
220 K 1 7/16" 1 7/8" 1 1/8" 1 3/8"
237 K 1 7/8" 2" 1 3/4"
254 K 2" 2" 2 3/16" 1 7/8"
MEASURED
DEFLECTION UNDER INCREASING LOAD
DEFLECTION UNDER DECREASING LOAD
COMPUTED DEFLECTION, UNREVISED
COMPUTED DEFLECTION, REVISED

Fig. 12 Deflection at panel points of north truss

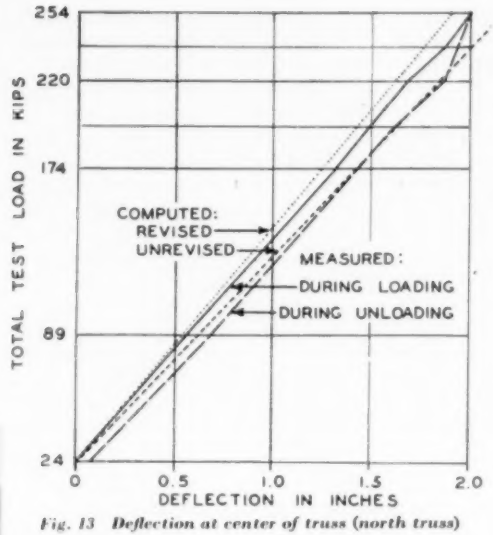


Fig. 13 Deflection at center of truss (north truss)

reached a maximum of $^3/_{16}$ in. and returned to $^1/_{16}$ in. upon removal of the load.

Figure 12 shows the deflection curve of the north truss under the loadings of Test 2. The curve for the south truss is substantially the same.

Figure 13 is a plot of the deflection at the center of the north truss. During removal of the load this deflection lagged as much as $^3/_{16}$ in. behind the corresponding deflection under application of the load. Upon removal of all the applied load the residual deflection at the center of each truss was $^1/_{16}$ in.

The computed deflections were obtained from a Williot diagram using the axial stresses of Fig. 8.

CONCLUSIONS

The purpose of the paper is essentially to present some of the results of this test which might be of general interest to structural engineers. No new theories were employed—the basic methods of computing the secondary stresses and the deflections of such a truss have long been accepted. However, the H-Section welded truss is different, in details, from the riveted or welded truss with gusset plates, for which these theories were originally developed.

Furthermore, strain gage tests of a pair of full-size 80-ft. trusses under a distributed load are not common.

It was stated initially that the absence of gusset plates—in fact all detail material—produced a truss which was in unusually close agreement with the common theory that each truss member has a constant cross section and moment of inertia for its full length between truss joints. Within the limitations of experimental errors this statement has been substantially confirmed by this test.

References

1 Waudelich, A. T., "H-Section Welded Trusses," THE WELDING JOURNAL, 26 (4): 327-331 (1947).

2 "H-Sections Form Standard Length Trusses," *Eng. News-Record*, 134: 122 (1945); also discussion 882-883.

Determination of Impurities in Inert Gases

Equipment and techniques for determining the impurities in the inert gases argon and helium

by R. E. Bowman and C. B. Hartley

Abstract

Equipment and techniques were developed for determining the total impurities in the inert gases, argon and helium, that are used in arc welding. The method that was used is based on the fact that molten lithium absorbs nitrogen, oxygen and water vapor. The gas sample was admitted into a constant volume apparatus where the impurities were removed by the molten lithium. The change in pressure at a standard temperature, produced by the removal of the impurities, was used to determine the purity of the gas. Since the total impurities in argon for welding was less than 0.2%, a special apparatus was constructed to minimize errors due to small changes in atmospheric pressure and temperature. The apparatus was satisfactory. The maximum error in the determinations was about 0.01% of the total volume. The impurities in the samples of argon that were tested averaged about 0.14% of the total volume.

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INTRODUCTION

THE inert gases, argon and helium, are now used extensively as a protective atmosphere in the welding and melting of metals. The purity of these gases must be high in order to obtain satisfactory

results in the welding and melting of some metals. Argon and helium having a purity above 99.8% are now available to meet this demand. When the purity of the gas is important, it is desirable to have convenient methods for determining the amount of impurities in the gas. It is also desirable to include these methods in specifications covering the procurement of the gas. A search was conducted in the available literature for suitable methods. This search revealed that suitable commercial equipment was available for the determination of oxygen, hydrogen and water vapor in small quantities. No commercial equipment was found that was considered satisfactory for routine determination of small amounts of nitrogen in argon. A suitable method, however, was described by J. H. Severyns, E. R. Wilkinson and W. C. Schumb in an article, "Use of Metallic Lithium in Analysis of Gases," published in *Industrial and Engineering Chemistry*, Oct. 15, 1932. This method was accurate to about 0.1% and was successful in determining the nitrogen concentration in helium ranging from 1.0 to 2.0%. The same method was used to analyze argon having a nitrogen content below 0.2% but was not successful due to the small pressure change which occurred when the nitrogen was absorbed by the molten lithium. The pressure change was less than one millimeter of mercury and could not be measured accurately with the apparatus due to the small variations in atmospheric pressure and temperature which would occur during the tests. A modification of this apparatus was constructed so that the errors due to small pressure and temperature variations were minimized and a more sensitive manometer was installed to measure the small pressure change caused by the absorption of the nitrogen.

DESCRIPTION OF THE APPARATUS

The apparatus that was constructed is shown in Fig. 1. It consists of two flasks, *E* and *F*, which are clamped in a Plexiglas tank which is filled with water to the level indicated. Flask *F* is connected by glass tubing to the left side of the Octoil manometer. Flask *E* is connected by glass tubing to the right side of the Octoil manometer and also to the left side of the mercury manometer. The heater, *K*, for melting the lithium is supported in Flask *E* near the bottom by the lead-in wires through the stopper *H*. The construction of the heater and the stopper is given in more detail in Fig. 2. The heater consists of a heating element from an automobile cigar lighter. A variable voltage transformer, connected to 110 v. a. c., was used as the power supply. The heater used about 10 amp. current at 6 v. The stopper has a stopcock for bleeding air into the flask when the absorption efficiency of the lithium is to be checked. The stopper has a ground tapered surface which fits that in the neck of the flash. A gastight joint is obtained by applying Cello-seal to the tapered surfaces before the plug is inserted in the flask. Means are provided for increasing the sensitivity of the Octoil manometer. This was accomplished by placing a hinge and a flexible connection at the top of the manometer as shown in Fig. 1. With this arrangement, the manometer can be inclined by swinging the bottom outward from the board. The adjustable bracket *M* holds the manometer in the inclined position. This feature, however, was not used as the Octoil manometer has sufficient sensitivity in the vertical position. Octoil, a fluid for vac-

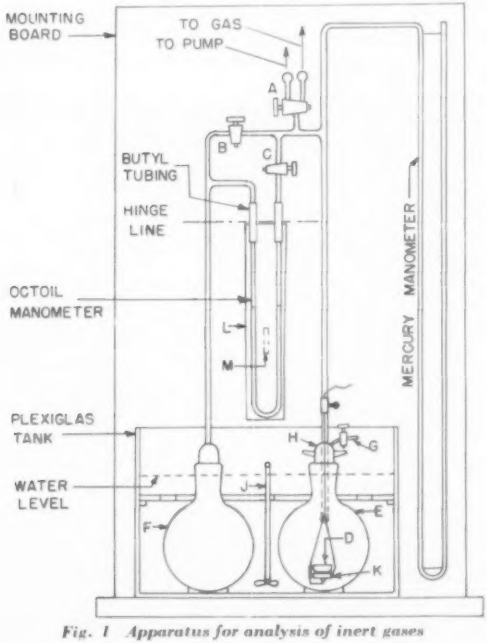

Fig. 1 Apparatus for analysis of inert gases

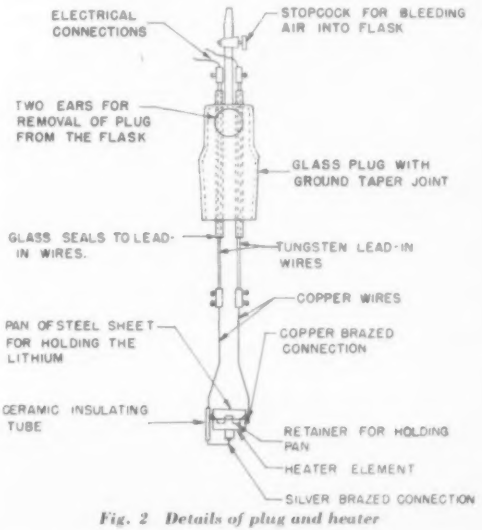
ELECTRICAL CONNECTIONS
STOPCOCK FOR BLEEDING AIR INTO FLASK
TWO EARS FOR REMOVAL OF PLUG FROM THE FLASK
GLASS PLUG WITH GROUND TAPER JOINT
GLASS SEALS TO LEAD-IN WIRES.
TUNGSTEN LEAD-IN WIRES
COPPER WIRES
PAN OF STEEL SHEET FOR HOLDING THE LITHIUM
COPPER BRAZED CONNECTION
CERAMIC INSULATING TUBE
RETAINER FOR HOLDING PAN
HEATER ELEMENT
SILVER BRAZED CONNECTION

Fig. 2 Details of plug and heater

uum pumps, was used in the manometer to increase the sensitivity. This fluid had a very low vapor pressure and a specific gravity of 0.98. The apparatus has the three stopcocks *A*, *B* and *C*. The three-way stopcock *A* permits either the evacuation of the apparatus or the admission of the gas sample. When stopcocks *B* and *C* are open the Octoil manometer is inactive. The stopcocks are in this position when the apparatus is evacuated or when gas is admitted. The Octoil manometer becomes active when Stopcock *B* is closed. Stopcock *C* is closed only during the heating and cooling period to prevent the excessive pressure in Flask *E* from forcing the fluid from the manometer. A motor-driven stirrer *J* is used to keep the water circulating so that a uniform temperature in the water bath will be maintained.

The extra Flask *F* provides a reference pressure which is used with the Octoil manometer in measuring the pressure change produced by the absorption of the impurities in Flask *E*. Flask *F* also provides temperature compensation since a small variation in the temperature of the water bath will produce corresponding variations of pressure in both flasks. With this arrangement, the indication of the Octoil manometer will not be affected by small variations in temperature of the gas. The usual variations in atmospheric pressure will not affect the indication of the Octoil manometer as the pressure in flask *F* is used as a reference instead of the atmosphere. If the extra flask and the Octoil manometer were not used, extreme accuracy would be required in measuring the temperature and pressure of the gas in order to determine the small pressure change due to the removal of 0.2% impurities.

The Octoil manometer is very sensitive and for this reason it is desirable to have some method of preventing excessive pressure from blowing the fluid out of the column. This is accomplished by increasing the cross section of each column at the top of the manometer. In this apparatus, the butyl tubing at the top of the manometer provided sufficient enlargement of the cross section. When the fluid reaches the enlargement, the gas will bubble through the fluid and release the pressure. After the fluid drains back into the manometer, the remaining gas bubbles can be forced out of the fluid by applying a pulsating pressure through Stopcock *G*. This moves the fluid up and down in the manometer and agitates the gas bubbles so they will rise out of the fluid. The fluid will remain in the manometer if the proper procedure is followed. It is, however, desirable to have the above protection in case of an accident or in case a leak develops in the apparatus.

PROCEDURE FOR TESTS

The gas cylinder and vacuum pump were connected to the three-way Stopcock *A* as indicated in Fig. 1. Butyl tubing containing no plasticizer was used for the gas connection to avoid possible errors due to vapors from the tubing. The gas line was purged by opening stopcocks *B* and *C*, removing *H* and turning Stopcock *A* to allow the gas to flow into the apparatus and out at the neck of flask *E*. The gas line was purged in this manner for about 5 min. with the flow at not less than 5 liters per minute. The heater, Flask *E* and the stopper were thoroughly cleaned with acetone and were dried with an air jet. A small cube of lithium was prepared by washing the surfaces with a solvent and then shaving the sides with a clean knife. The lithium was placed in the pan on the heater. The plug with Cello-seal on the tapered surface was inserted in Flask *E*. The apparatus was evacuated with stopcocks *B* and *C* open. The gas was then admitted until the pressure was approximately 60 mm. below the atmospheric pressure. After a period of approximately 30 min., Stopcock *B* was closed and the indication of the Octoil manometer was observed for an additional 30 min. There should be no movement of the manometer during the latter period. Failure of the manometer to balance indicates that insufficient time was allowed for the gases in the two flasks to arrive at the same temperature or that there is a leak in the apparatus. After the manometer was balanced, Stopcock *C* was closed and the heater was turned on. The lithium was heated to about 500° C. and maintained at this temperature for approximately 1 hr. At the end of this period the heater was turned off and the gas was allowed to cool. Immediately after the heater was turned off, the water bath was cooled to the starting temperature by dropping dry ice in the tank. When the gas had cooled for 30 min., Stopcock *C* was opened and the Octoil manometer would indicate the difference in pressure between the two flasks. The manometer was observed until the indication was constant for 30 min. or longer. The manometer will usually reach a constant indication

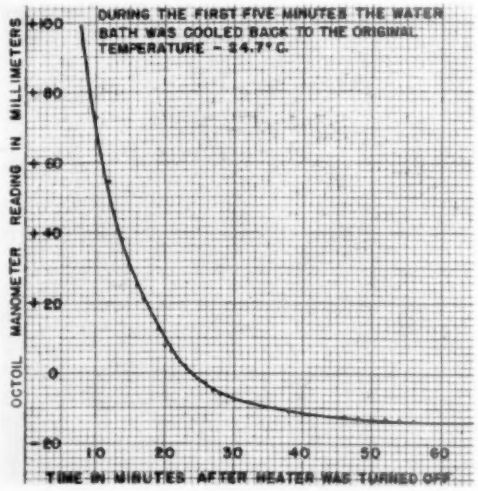

Fig. 3 Cooling curve showing the differential pressure between the two flasks as a function of time after the heater was turned off

within 1 hr. A typical cooling curve was plotted in Fig. 3. The Octoil manometer indicated the change in pressure due to the absorption of the impurities.

The first determination, made with a given sample of lithium, was discarded in order to avoid possible errors due to the liberation of extra gases from the heater and the lithium during the first heating. Although great care was exercised in cleaning, it was difficult to prevent the liberation of a small amount of white smoke on the first heating. After the first determination, the apparatus was evacuated with the same sample of lithium in place and a second determination was made using the same procedure. Several determinations were made using the same sample of lithium. This was possible as the purity of the gas was high.

Errors due to insufficient purging of the line between the gas cylinder and the apparatus were minimized by purging the line before each determination. This was accomplished by turning Stopcock A to admit the gas, allowing the pressure to rise slightly above atmospheric opening Stopcock G on Plug H and allowing the gas to flow for about 5 min. The determination was then made using the usual procedure. The determinations made before and after purging should check.

CALCULATIONS

The following formula was used in calculating the percentage of impurities:

$$\%\text{ impurities} = 7.24\frac{D}{P} + \frac{7.07D}{10{,}000}$$

D = change in pressure in millimeters of Octoil due to absorption of impurities (as indicated by manometer).

P = pressure of gas in millimeters of mercury.

The second term is a correction for the change in volume due to the movement of the Octoil in the manometer. This correction is small (about 0.008% of the total volume) and may be neglected if the ultimate in accuracy is not required. This formula was derived by starting with the expression:

$$\%\text{ impurities} = \frac{\Delta P}{P} \times 100$$

ΔP = change in pressure caused by the absorption of the impurities.

This expression is true if there is no change in temperature or volume. There is, however, a small change in volume, ΔV, due to the movement of the fluid in the manometer. The change in volume for Flask F is:

$$\Delta V = \frac{DA}{2 \times 10}\text{ cu. cm.}$$

A = area of the bore in tube.

Since the diameter of the bore was 3 mm., the following expression may be used for ΔV.

$$\Delta V = 0.00354D\text{ cu. cm.}$$

The corresponding pressure change, $\Delta P'$, was calculated using

$$\frac{V + \Delta V}{V} = \frac{P}{P + \Delta P'}$$

or

$$\Delta P' = \frac{-\Delta V P}{V + \Delta V}$$

Since the volume change is small a very close approximation is obtained by the expression:

$$\Delta P' = \frac{\Delta V}{V} P$$

The above expression represents the increase in pressure which will be produced when the gas in Flask F is restored to the original volume. There is a corresponding decrease in pressure when the gas in Flask E is restored to the original volume. Thus, the total correction required to compensate for the volume change is $2\Delta P'$. Since 1-liter flasks were used, the value for V is 1000 cu. cm. When the values for V and ΔV are substituted in the equation, the total correction, C, is

$$C = \frac{0.00707DP}{1000} = \frac{7.07DP}{1{,}000{,}000}\text{ mm. Hg.}$$

The difference in pressure between the two flasks is measured in millimeters of Octoil which is converted to millimeters of mercury by the expression:

$$\Delta P'' = \left(\frac{\text{Density of Octoil}}{\text{Density of Mercury}}\right)D = \frac{0.98}{13.55}D = 0.0724D$$

The corrected pressure change, ΔP, due to the absorption of the impurities is:

$$\Delta P = \Delta P'' + C = 0.0724D + \frac{7.07DP}{1{,}000{,}000}\text{ mm. Hg.}$$

The percentage of impurities is obtained by dividing by P and multiplying by 100

$$\%\text{ impurities} = 7.24\frac{D}{P} + \frac{7.07D}{10{,}000}$$

The correction for the volume change would not be necessary if tubing of a smaller bore (1 mm.) were used. The larger bore was used so that the gas bubbles could be more easily removed after an accident in which the fluid was forced out of the manometer as explained before. The mercury manometer also had a bore of 3 mm., but here the movement of the column did not exceed 0.5 mm. during a test. In this case the volume change could be neglected.

DISCUSSION OF RESULTS

Results of a typical series of determinations made on samples of argon from a commercial cylinder are tabulated below:

Test No.	Differential pressures, mm. Octoil	Differential pressures, mm. Mercury	Atmospheric pressure, mm.	Gas pressure, mm.	Impurities, %
1	−11.5	−61	746.3	685.3	0.130
2	−12.5	−67	746.2	679.2	0.142
3	−12.0	−68.5	747.1	678.6	0.136

Successive determinations of a gas sample would usually be within $\pm 0.01\%$ of the average value.

The possibility of errors due to the absorption of impurities at room temperature during the period preceding the heating of the lithium was investigated. A sample of gas from the same cylinder that was used in the above determinations was admitted into the apparatus. The temperature of the gas in the two flasks was equalized as described before. Then the two flasks were isolated by turning Stopcock *B* and the apparatus was allowed to stand for 16 hr. At the end of this period the Octoil manometer indicated a pressure difference of +1 mm. The higher pressure was in Flask *E*, containing the lithium. This difference in pressure may have been due to a small leak. The pressure in the two flasks was equalized by opening Stopcock *B* for a few seconds and a determination was then made in the usual manner. In this determination, the impurities were 0.148% of the total volume. This value is slightly higher than those obtained in the preceding tests. The difference corresponds to the pressure change that occurred during the 16-hr. period. This fact indicates that the difference in values may be due to a small leak in Flask *E* and that there was no appreciable absorption of impurities during the 16-hr. period.

The absorption efficiency of the lithium can be checked after each series of determinations. After the gas in Flask *E* has cooled down, the indication of the Octoil manometer is recorded. This indication is that due to the absorption of impurities in the preceding determination. Stopcock *G* is opened a slight amount to admit air into Flask *E* until the Octoil manometer returns to zero or slightly beyond zero. The lithium is heated in exactly the same manner as before. The gas is allowed to cool back to the original temperature and the indication of the Octoil manometer is recorded again. There should be no difference in the two indications if the lithium absorbed all of the impurities. Repeated checks made in this manner showed that the Octoil manometer would consistently return to original position. The variation was within the accuracy of reading the manometer. Although the percentage of impurities was small, the absorption was practically complete. The high degree of absorption must be due to the formation of lithium vapor which is mixed with the gas by diffusion and convection currents.

Lithium absorbs nitrogen, water vapor and oxygen. The percentage of oxygen, water vapor and other impurities in argon is usually so small that the indication of the Octoil manometer may be considered as being caused by nitrogen. Commercial equipment, however, is available for the determination of oxygen and water vapor in low concentrations.

CONCLUSIONS

The apparatus was satisfactory for checking the purity of the inert gases in commercial cylinders. The maximum error in the determinations was about $\pm 0.01\%$ which is not objectionable in checking the gas for compliance to specifications. It is believed that the accuracy of the apparatus can be improved somewhat by using more care in the construction and by installing more sensitive manometers. The apparatus has the advantage that calibration is not necessary since it is based on measuring the pressure change produced by the absorption of the impurities. The chief disadvantage is that a long time is required to make a determination. This is due to the long heating and cooling periods.

Discussion on "The Statistical Part in Welding Investigations"

by N. L. Navarre and W. E. Clautice

THE authors feel that they can best discuss the paper, so well presented by Miss Day, by describing an application of statistical planning to laboratory evaluation tests performed on the Clip Test.

N. L. Navarre and **W. E. Clautice** are connected with the Welding and Electrical Laboratory, U. S. Naval Engineering Experiment Sta., Annapolis, Md.

The paper by B. B. Day was published in THE WELDING JOURNAL, **28**, (10) Research Suppl., 449-s to 461-s (1949).

The clip test is a weldability field or "spot" test originated by the Portsmouth Naval Shipyard for use in discriminating between those high-tensile steels which exhibit underbead cracking tendencies and those which do not. Subsequent work performed with the Clip Test by various activities showed that the test had possibilities but that the results obtained were at variance. Further investigation with a view toward developing a standardized procedure was assigned to the U. S. Naval Engineering Experiment Station.

For this purpose, the Experiment Station employed

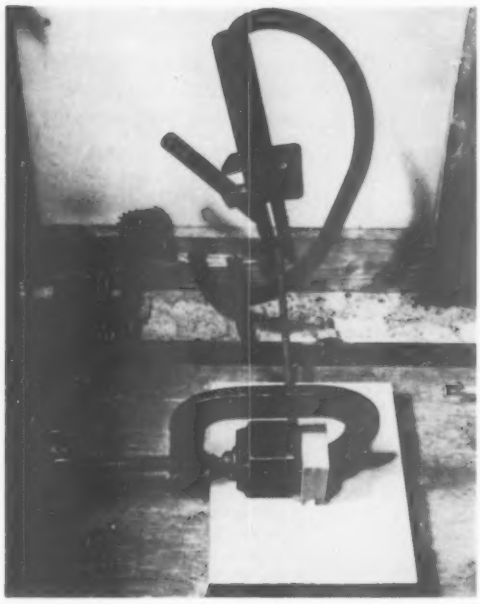

Fig. 1 Clip Test setup in constant temperature cabinet

the Firecracker method of electrode deposition. Figure 1 illustrates this method. A mild-steel clip is tacked to the center of a typical test specimen. The electrode is laid horizontally in the T-joint formed by the clip and the plate and is clamped in place by means of a copper block that was developed empirically for that purpose. The arc is started by shorting the electrode against the plate with a carbon pencil and from there on the electrode is self consuming throughout the length of the copper block and then the stub falls free extinguishing the arc and completing the welding sequence. The mild-steel clips were broken from the sections of high-tensile steel plate 24 hr. after welding. The types of fractures obtained gave an indication of the weldability of the steel plate. A transweld type of fracture or break through the weld bead is an indication of good weldability. An underbead type of fracture or pull-out from the plate under the weld bead is an indication of poor weldability.

FOUR TEMPERATURES AND THREE ELECTRODE SIZES WERE EMPLOYED TO YIELD A TOTAL OF 12 POSSIBLE COMBINATIONS.

ELECTRODES	TEMPERATURES
1/8" Dia. = D_1	120°F = T_1
3/16" Dia. = D_2	70°F = T_2
1/4" Dia. = D_3	20°F = T_3
	-40°F = T_4

COMBINATIONS

D_1T_1	D_2T_1	D_3T_1
D_1T_2	D_2T_2	D_3T_2
D_1T_3	D_2T_3	D_3T_3
D_1T_4	D_2T_4	D_3T_4

Fig. 2 Legendary for the statistical design

Evaluation tests next were performed. It was decided to investigate the effects on the welding procedure of electrode size, temperature of the plate just prior to welding and also the effect of test welding in different areas of the same steel plate. These factors were investigated by means of statistical planning of test procedures and analysis of data.

Figure 2 shows the legendary used in the statistical designing. The three electrode sizes used in the test and the four plate temperatures at the start of welding are shown with designating symbols allowing a total of 12 possible combinations. This is known as a factorially designed test. One complete set of 12 forms a "replication." Each replication forms a block. Five replications or blocks were run for each plate. This allowed five repeats for each of the 12 combinations for each plate or in statistical terms, samples of five.

	B_1			B_2		B_3			B_4		B_5	
38"	1 D_1T_1	6 D_2T_2	11 D_3T_4	16 D_1T_2	21 D_2T_3	26 D_1T_2	31 D_3T_3	36 D_2T_3	41 D_2T_3	46 D_1T_2	51 D_3T_3	56 D_2T_4
	2 D_3T_3	7 D_1T_3	12 D_1T_2	17 D_3T_2	22 D_2T_2	27 D_3T_2	32 D_3T_4	37 D_1T_1	42 D_1T_4	47 D_1T_3	52 D_1T_2	57 D_2T_3
	3 D_2T_3	8 D_1T_4	13 D_3T_4	18 D_2T_4	23 D_3T_1	28 D_1T_4	33 D_1T_1	38 D_2T_4	43 D_3T_3	48 D_3T_4	53 D_1T_4	58 D_3T_4
	4 D_2T_4	9 D_3T_2	14 D_1T_4	19 D_1T_1	24 D_2T_1	29 D_2T_2	34 D_1T_3	39 D_2T_1	44 D_3T_1	49 D_2T_1	54 D_1T_1	59 D_3T_1
7½"	5 D_3T_1	10 D_2T_1	15 D_3T_3	20 D_1T_3	25 D_2T_1	30 D_2T_4	35 D_3T_1	40 D_3T_2	45 D_2T_2	50 D_1T_3	55 D_3T_2	60 D_2T_2

6" → 72"

Fig. 3 Random arrangement of plate for Clip Test welding experiment

Steel of proven underbead cracking tendencies. Each coupon 6 x 7½ in. as shown

FIRST PLATE						SECOND PLATE				
UNDERBEAD FRACTURES AT TEMPERATURE					SIZE OF ELECTRODE DIAMETER	UNDERBEAD FRACTURES AT TEMPERATURE				
120°F.	70° F.	20° F.	-40°F.	TOTAL		120°F.	70° F.	20° F.	-40°F.	TOTAL
1	1	3	1	6	1/8"	0	1	1	1	3
1	3	5	5	14	3/16"	0	0	4	5	9
0	2	5	3	10	1/4"	0	0	0	1	1
2	6	13	9	30	TOTAL	0	1	5	7	13

Fig. 4 Comparison of steel plates used in the Clip Test showing the relative effects of electrode size and plate temperatures at the start of welding

Two plates were available for the purposes of the test. Figure 3 shows the statistical dissection plan for the first of these plates. This plate was submitted as being of proven underbead cracking tendencies. It was divided into five areas or blocks. Each block was further subdivided into 12 specimens. The 12 statistical combinations were assigned in a random order to the 12 specimens in each block. The tests were conducted in numerical sequence, 1 through 60, as indicated.

The second plate, which was submitted as being free of underbead cracking tendencies, was dissected following a similar pattern, except, of course, the randomization differed.

Figure 4 shows some results pertaining to the statistical analysis showing the number of underbead fractures obtained for each plate, arranged so as to give an indication of the relative effects of electrode sizes and plate temperatures at the start of welding. Data for the plate of proven underbead cracking tendency are on the left. Data for plate submitted as being free of underbead cracking are on the right. As the plate temperature at the start of welding was lowered, an increasing number of underbead fractures was obtained for each plate. The greater discriminating power of the $^3/_{16}$-in. diameter electrode is indicated. This size of electrode gave a progressively increasing number of underbead fractures as the temperature of welding was lowered.

Also, the $^3/_{16}$-in. diameter electrode size gave an indication of a cracking threshold as existing between 70 and 20° F. for the plate submitted as being free of underbead cracking tendencies. By performance of corollary tests, the cracking threshold was found to exist between 70 and 50° F. for this plate.

PLATE	FRACTURES		
	UNDERBEAD	TRANSWELD	ALL
FIRST PLATE	30	30	60
SECOND PLATE	13	47	60
TOTAL	43	77	120

THERE WAS SUFFICIENT EVIDENCE TO INDICATE THAT THE CLIP TEST WOULD DISCRIMINATE BETWEEN THE TWO PLATES WITH A LESS THAN 1 IN 1000 CHANCE THAT THE DIFFERENCE MIGHT HAVE BEEN ACCIDENTAL

Fig. 5 Summary of Clip Test data

Figure 5 gives the data in summary form. The data for the first plate show 30 underbead fractures and 30 transweld fractures for the 60 tests performed on this plate. The data for the second plate show 13 underbead fractures and 47 transweld fractures for the 60 tests performed on this plate. This gives a total of 43 underbead fractures and 77 transweld fractures for the 120 tests performed.

There was sufficient evidence from the statistical analysis to indicate that the Clip Test performed by the firecracker method would discriminate between the two plates employed with a less than 1-in-1000 chance that the difference might have been accidental.

The statistical study of the block effect showed no significant difference between the results obtained by performing the test welding in different locations of the same plate.

Based on the results obtained in the above described evaluation test, the Clip Test was recommended for the purposes of the Naval Service.

NOTE: The opinions given in the above discussion are those of the writer and do not necessarily coincide with the official views of the Navy Department.

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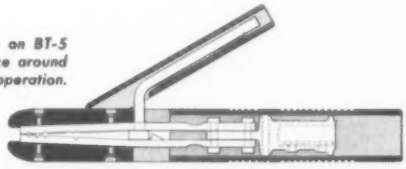

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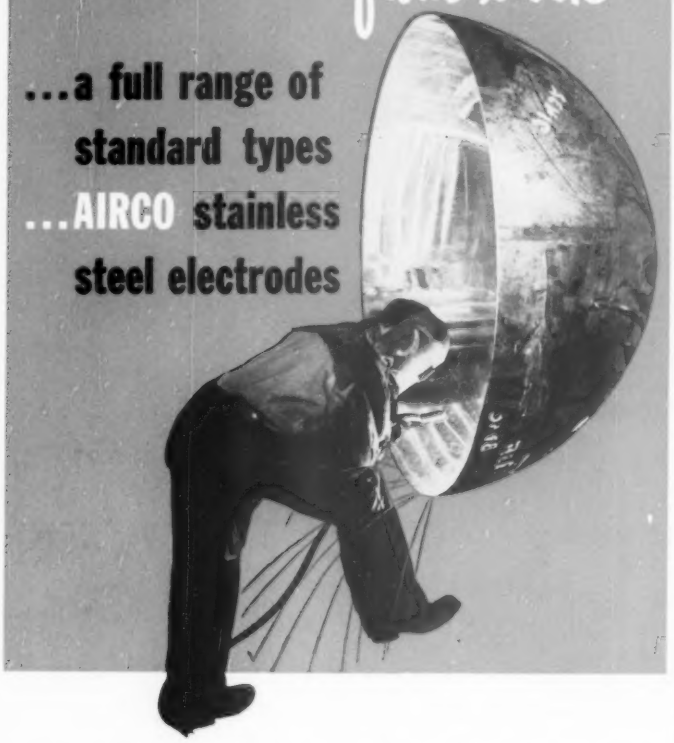

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